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THE ALGEBRAIC NUMBERS AND DIVISION[1]

As to what should most appropriately be the character of an address delivered on an occasion such as the present I am not quite certain. Whether it were better that one should be somewhat general and discursive in his remarks or whether he would be justified in offering a considerable amount of highly specialized and technical material I hardly know. Possibly a critical or historical survey of some subject would be more in place, or again under circumstances it might perhaps be permitted to the speaker to discuss some phase or aspect of a special field which would afford opportunity to present, among others, results obtained by himself or to develop methods employed in his investigations.

On this occasion I shall venture to say a little about a subject in which I have had a special interest, but in which results obtained are of some years' standing, since with the routine of teaching, executive activities in various connections and a vast amount of organizing work have, in recent years, combined to prevent productive effort and have interfered with the formulation for publication of results already there.

What I have to say will consist largely in statements. There will be no attempt to give proofs. These will be available elsewhere. A certain amount of recapitulation of more or less familiar facts will be necessary in order to establish connectivity, and as a preliminary to the later statements. The net result, I trust, will be found to contain an element of novelty.

An integer can be represented as a product of powers of primes, the exponents being positive integers. A rational fraction can be represented as a product of powers of primes, the exponents being positive or negative integers. The exponent of a given prime in the representation of a rational number as a product of powers of primes we call the order number of the rational number for the prime in question. We say that 0 is the order number of a rational number for a prime which does not appear explicitly in the representation of the number as a product of powers of primes. One rational number we say is divisible by another when the quotient of the first number by the second is integral, otherwise

[1] Address of the retiring vice-president and chairman of Section A—Mathematics—American Association for the Advancement of Science, Kansas City, Mo., December, 1925.

said, when for every prime p the order number of the former is at least as great as the corresponding order number of the latter.

Besides the product representation just referred to there is also for any positive integer r and with reference to a single prime p a unique representation in the form

$$(1) \qquad r = a_0 + a_1 p + \cdots + a_{k-1} p^{k-1}$$

where each of the coefficients $a_0\ a_1, \cdots, a_{k-1}$ is one of the numbers $0, 1, \ldots, p-1$.

We shall for the moment say of a rational number $r = s/q$ represented in its reduced form, as the quotient of two integers, that it is divisible by a power of the prime p if its numerator is divisible by that power of p. We can then make use of the notation of congruences and find coefficients $a_0, a_1, \cdots, a_{k-1}$ included among the integers $0, 1, \ldots, p-1$ such that, however great k may be, we have

$$(2) \qquad r \equiv a_0 + a_1 p + \cdots + a_{k-1} p^{k-1} \pmod{p^k}$$

provided the denominator q is not divisible by p. This holds whether r is positive or negative. We can multiply both sides of the congruence by a negative power of p, the modulus being at the same time multiplied by this power of the prime. It is then evident that we can include the case where the denominator q is divisible by a power of p on writing

$$(3) \qquad r \equiv a_{-l} p^{-l} + a_{-l+1} p^{-l+1} + \cdots + a_{-1} p^{-1} + a_0 + a_1 p + \cdots + a_{k-1} p^{k-1} \pmod{p^k}$$

where the coefficients $a_{-l}, a_{-l+1}, \cdots a_{-1}, a_0, a_1, \cdots a_{k-1} \cdots$ are all to be found among the numbers $0, 1, \cdots, p-1$.

Continuing the series on the right-hand side of (3) out to infinity we write

$$(4) \qquad r = a_{-l} p^{-l} + a_{-l+1} p^{-l+1} + \cdots + a_{-1} p^{-1} + a_0 + a_1 p + \cdots + a_{k-1} p^{k-1} + \ldots (p)$$

The coefficients in the series on the right-hand side of (4) constitute a perfectly definite sequence.

A series in ascending powers of p with a definite sequence of integral rational numbers as coefficients we shall designate as a p-adic number. Hensel defines the p-adic numbers more generally and develops their theory in his book "Theorie der Algebraischen Zahlen." For the purposes of the present paper, however, the more general p-adic numbers are superfluous and the elementary p-adic numbers to which we here restrict ourselves throw light on the subject of the algebraic numbers and suffice for the development of a simple theory of the ideals.

A positive integer r might be represented as a polynomial in p with coefficients which are not all included among the numbers $0, 1, \cdots, p-1$. We then have a simple process by which from such representation we can obtain in succession the coefficients $a_0, a_1, \cdots, a_{k-1}$ in the form of representation given in (1) where these coefficients are included among the numbers $0, 1, \cdots, p-1$. The same process applied to any p-adic number whose coefficients are not all included under the numbers in question will give us a p-adic number with a sequence of coefficients which are included under these numbers. The p-adic number so obtained is regarded as equivalent to the p-adic number from which it was deduced and is referred to as the reduced p-adic form of that number.

The sum, difference, product of two integral p-adic numbers $a_0 + a_1 p + \cdots$ and $b_0 + b_1 p + \cdots$ are, respectively, taken as

$$a_0 + b_0 + (a_1 + b_1) p + \cdots,$$
$$a_0 - b_0 + (a_1 - b_1) p + \ldots,$$
$$a_0 b_0 + (a_0 b_1 + a_1 b_0) p + \cdots.$$

Each of these can be expressed as a reduced p-adic number. Also the quotient

$$a_0 + a_1 p + \cdots / b_0 + b_1 p + \cdots$$

can be obtained directly as a reduced p-adic number $c_0 + c_1 p + \cdots$ in the case where the denominator is not divisible by p, on writing

$$(b_0 + b_1 p + \cdots)(c_0 + c_1 p + \cdots) = a_0 + a_1 p + \cdots (p)$$

and determining the coefficients $c_0, c_1, \cdots$ in succession by the aid of congruences (mod p). It is evident what modifications are to be introduced in defining and obtaining the sum, difference, product or quotient of two p-adic numbers where negative powers of p present themselves.

We have seen that to every rational number corresponds a definite p-adic number of reduced form which may be said to characterize that number relatively to the prime p or to which the rational number may in a certain sense, with reference to p, be said to be equal. Conversely, however, it does not follow that to every reduced p-adic number there corresponds a rational number, which is represented by it in the p-adic field.

By the order number of a p-adic number we shall mean the lowest exponent in its series. In the case of a rational number then this p-adic order number coincides with what we have called the order number of the rational number relative to the prime p.

It is evident that the p-adic order number of a sum or difference of two p-adic numbers is equal to the lesser of the order numbers of the p-adic numbers when these order numbers are unequal and that in the case where they are equal the order number of the sum or difference in question is at least equal to the common order number of the two p-adic numbers. The p-adic order number of a product is equal to

the sum of the p-adic order numbers of the factors and the p-adic order number of a quotient is equal to the difference between the order number of the numerator and the order number of the denominator.

Consider an algebraic equation

(5) $$f(x) = x^n - \alpha_1 x^{n-1} + \ldots + (-1)^n \alpha_n = 0$$

in which the coefficients are rational numbers. If x^n had a coefficient $\alpha_0 \neq 1$ division by α_0 would reduce the equation to the form in question. Equation (5) is said to be integral if the coefficients are all integral. If the equation is not integral a substitution $y = \alpha x$ where α is an integer will give us an equation in y which is integral. Equation (5) may or may not be irreducible in the field of the rational numbers. It is in any case equivalent to a number of equations which are irreducible in the field of the rational numbers. If the equation (5) is integral each of these irreducible equations, it can be shown, is integral. Any root of an irreducible algebraic equation is called an algebraic number. Such root is called integral if the irreducible equation is integral. All the roots of an algebraic equation then are algebraic numbers and all the roots of an integral algebraic equation are integral algebraic numbers.

Any number built up by addition, subtraction, multiplication and division out of the rational numbers and a finite number of algebraic numbers can be shown to be an algebraic number. The quotient of two algebraic numbers is then an algebraic number, and one algebraic number is said to be divisible by a second algebraic number when the quotient of the former by the latter is an integral algebraic number.

Supposing equation (5) to be irreducible in the field of the rational numbers let us consider the body of numbers built up by rational operations out of one of its roots ε. The field or corpus of algebraic numbers so obtained we designate by $C(\varepsilon)$. Any number $R(\varepsilon)$ of the corpus can be represented as a polynomial of degree $n-1$ in ε with rational coefficients.

$R(\varepsilon)$ is a root of an algebraic equation of degree n

(6) $$F(X) = X^n - A_1 X^{n-1} + \ldots + (-1)^n A_n = 0,$$

where the coefficients A are rational. This equation may or may not be reducible. If it is reducible, however, the left-hand side is a power of an irreducible polynomial in X. If it is irreducible its root $e = R(\varepsilon)$ is a primitive number of the corpus, that is to say the corpus $C(e)$ coincides with the corpus $C(\varepsilon)$.

Within the corpus $C(\varepsilon)$ we designate A_1 and A_n as trace and norm, respectively, of the number e. The trace and norm of ε are α_1 and α_n, respectively.

Though the polynomial on the left-hand side of equation (5) is irreducible in the field of the rational numbers it may so happen that it is reducible in the field of the p-adic numbers. We may then write

(7) $$f(x) = f_1(x) \ldots f_r(x) \quad (p)$$

where

$$f_i(x) = x^{n_i} - a_1^{(i)} x^{n_i - 1} + \cdots + (-1)^{n_i} a_{n_i}^{(i)},$$

the coefficients $a_s^{(i)}$ here being p-adic numbers. It is to be understood that there is here no question of equating the p-adic factors to 0.

If $f(x)$ is p-adically integral, that is to say, if its coefficients are integral relatively to the prime p, so also are the coefficients in the factors $f_i(x)$ p-adically integral, as may readily be shown. These factors we shall assume to be irreducible in the p-adic field. We shall associate the term *cycle* with these factors and shall speak of the first, second, etc., rth cycles in regard to the polynomial $f(x)$ and with reference to the prime p. As ith p-adic partial trace and ith p-adic partial norm of ε with reference to the specific prime p and within the corpus $C(\varepsilon)$ we shall designate $\alpha_1^{(i)}$ and $\alpha_{n_i}^{(i)}$ respectively—or we may speak of the p-adic partial trace and the p-adic partial norm of ε for the ith cycle. The sum of the r p-adic partial traces of ε corresponding to a specific prime p is evidently equal to the trace of ε and the product of the r p-adic partial norms of ε is equal to the norm of ε.

Where $f(x)$ splits into r irreducible p-adic factors $f_i(x)$ it can be shown that $F(X)$ will also split into r p-adic factors $F_i(X)$ which may or may not happen to be irreducible. We can then write

(8) $$F(X) = F_1(X) \ldots F_r(X) \quad (p)$$

where

$$F_i(X) = X^{n_i} - A_1^{(i)} X^{r_i - 1} + \cdots + (-1)^{n_i} A_{n_i}^{(i)},$$

There is a certain correspondence between the r p-adic factors of $F(X)$ and the r p-adic factors of $f(x)$ which we may assume to be indicated by their suffixes, the factor $F_i(X)$ of $F(X)$ corresponding to the factor $f_i(x)$ of $f(x)$. As $f_i(x)$ is irreducible in the p-adic field it can readily be shown that the corresponding factor $F_i(X)$ of $F(X)$ is either an irreducible p-adic polynomial or a power of such a polynomial. If then $F(X)$ is irreducible in the field of the rational numbers it is clear that the r p-adic factors $F_i(X)$ must be p-adically irreducible and distinct from one another. It can be shown that the correspondence between the factors $F_i(X)$ and $f_i(x)$ is independent of the choice of a primitive number to represent the numbers of the corpus.

The ith p-adic partial trace $\alpha_1^{(i)}$ of ε has a certain order number relative to the prime p, which we shall refer to as the p-adic partial trace order of ε corresponding to the ith cycle. Because of the correspondence between the factor $F_i(X)$ of $F(X)$ and the factor $f_i(x)$ of $f(x)$ one may speak of the order number of $A_1^{(i)}$ as the p-adic partial trace order of

$R(\varepsilon)$ corresponding to the ith cycle. The quotient by n_i of the order number of the p-adic partial norm $a_{n_i}^{(i)}$ we define as the order number of ε for the ith cycle. The order number of $R(\varepsilon)$ for the ith cycle is the quotient by n_i of the order number of the p-adic partial norm $A_{n_i}^{(1)}$. The order number of any number of the corpus for the ith cycle is then an integral multiple of $1/n_i$, it may be an integral multiple of $1/\nu_i$ where ν_i is a factor of n_i. A p-adic order number of a number of the corpus, one might note, is never greater than its partial trace order corresponding to the same cycle.

Any number of the corpus $C(\varepsilon)$ then has r p-adic order numbers relative to the prime p, these order numbers corresponding to the r cycles and being integral multiples of $1/\nu_1, 1/\nu_2, \ldots, 1/\nu_r$, respectively, where $\nu_1, \nu_2, \ldots, \nu_r$ are certain factors of $n_1, n_2, \cdots, n_r$. Writing $n_i = e_i\nu_i$ we call e_i the grade of the ith cycle, ν_i its order, and n_i its degree. It is to be noted that e_i is the smallest possible positive order number which can be possessed by the ith p-adic partial norm of a number of the corpus and that $1/\nu_i$ is the smallest positive order number of a number of the corpus for the ith cycle. It will be convenient to make use of the term coincidence with reference to an element $1/\nu_i$ considered as a constituent of an order number relative to the ith cycle.

It can be readily shown that a p-adic polynomial $g(x)$ which is irreducible or a power of an irreducible p-adic polynomial, is integral if its two end terms are integral. In the product for $f(x)$ given in (7) then, the several p-adic factors $f_i(x)$ are or are not integral according as their norm terms are or are not integral. The polynomial $f(x)$ itself is however p-adically integral or not according as its factors $f_i(x)$ are all p-adically integral or not. The necessary and sufficient condition that $f(x)$ be p-adically integral is that the norm terms in all its irreducible p-adic factors $f_i(x)$ be p-adically integral. This is evidently equivalent to saying the necessary and sufficient condition that $f(x)$ be integral relatively to the prime p is that the order numbers for the r cycles corresponding to p be all 0 or positive.

Similarly, the necessary and sufficient condition that $F(X)$ be integral relatively to the prime p is that the norm terms in its factors $F_i(X)$, as given in (8) be p-adically integral and this is the case whether $F(X)$ is irreducible in the field of the rational numbers or is the power of a polynomial irreducible in this field. This is equivalent to the statement that $F(X)$ is or is not integral relatively to the prime p according as the order numbers of $R(\varepsilon)$ for the corresponding r cycles are or are not all 0 or positive.

What we have arrived at is the following: In a corpus $C(\varepsilon)$ there are, corresponding to a given prime p, a certain number r of cycles. Each number of the corpus will have a specific set of order numbers $\tau_1, \ldots, \tau_r$ corresponding to these cycles, these order numbers being integral multiples of certain numbers $1/\nu_1, \ldots, 1/\nu_r$ respectively. The equation satisfied by the number $R(\varepsilon)$ in question will or will not be integral relatively to the prime p according as the r corresponding order numbers of $R(\varepsilon)$ are or are not all 0 or positive.

In order that an algebraic number ε should be integral in the ordinary sense it is necessary and sufficient that the equation which defines it should be integral relatively to all primes p. The necessary and sufficient conditions then that an algebraic number ε should be integral is that its cyclic order numbers for all primes p should all be 0 or positive.

For the sum or difference of two algebraic numbers of the corpus $C(\varepsilon)$ the p-adic order number corresponding to a given cycle is readily shown to be the smaller of their order numbers where these order numbers are unequal and in the case where they are equal the order number of the sum or difference, as the case may be, will be equal to or greater than the common order number of the numbers added or subtracted. The order number of the product of two numbers for a given cycle is equal to the sum of the order numbers of the factors corresponding to that cycle and for the cycle in question the order number of the quotient of two numbers is obtained on subtracting the order number of the denominator from the order number of the numerator.

Being given two or any larger finite number of algebraic numbers it is always possible to include them under one corpus. It is then evident that for divisibility of one algebraic number by another it is necessary and it suffices that the order number of the latter number for a cycle in no case exceeds the corresponding order number of the former number.

In illustration consider an irreducible quadratic equation

$$ax^2 + bx + c = 0 \tag{9}$$

where a, b, c are integers whose G, C, D, is 1. This equation we may replace by the equation

$$y^2 - \Delta = 0 \tag{10}$$

on writing $\delta^2 \Delta = D = b^2 - 4ac$, $\delta y = 2ax + b$ where δ^2 takes account of any square factor which may present itself in D. Any prime factor in Δ then presents itself to the first power only.

Designating by ε a root of the equation (9) the corpus $C(\varepsilon)$ coincides with the corpus $C(\sqrt{\Delta})$. The cycles which present themselves in this corpus are of orders 1 and 2. There are four cases to be considered in this connection. In each of the first three cases we have to deal with the question of the p-adic factorization of the left-hand side of the equation

(10) with reference to a prime p which is not a factor of Δ. The fourth case takes account of those primes p which are factors of Δ.

Case I. In this case we have to do with an odd prime p of which Δ is a quadratic residue. Here, as is well known, we can solve the congruence

$$y^2 \equiv \Delta \pmod{p^k} \tag{11}$$

however great the exponent k may be. That is to say, there exists a p-adic number $a_0 + a_1 p + \cdots$ which substituted for y satisfies the equation

$$y^2 - \Delta = 0 \qquad (p). \tag{12}$$

It is then readily seen that we have two p-adic numbers P_1 and P_2 such that identically

$$y^2 - \Delta = (y - P_1)(y - P_2) \qquad (p).$$

It is evident that $P_2 = -P_1$.

The p-adic solutions of equation (9) are obtained on writing

$$2ax + b = \delta y = \delta P_1,\ 2ax + b = \delta y = \delta P_2.$$

The order numbers of the p-adic series satisfying equation (9) are evidently neither of them negative unless a is divisible by p. If a is divisible by p one at least of these order numbers is negative. In this case the cycles are two in number, each of order 1.

Case II. Suppose p to be an odd prime, of which Δ is a quadratic non-residue. The congruence (11) is then not satisfied by a p-adic series and equation (10) is irreducible in the p-adic field. There is then only one cycle corresponding to the prime p and a number $R(\varepsilon)$ has only one order number for this prime. Also the norm of a number $R(\varepsilon) = \dfrac{t + u\sqrt{\Delta}}{v}$ is $\dfrac{t^2 - \Delta u^2}{v^2}$. Since however Δ is a quadratic non-residue (mod p) we know that there do not exist relatively prime numbers t and u such that $t^2 - \Delta u^2 \equiv 0 \pmod{p}$. The norm $\dfrac{t^2 - \Delta u^2}{v^2}$ then can not be divisible by p unless both t and u are divisible by p. It follows that if the norm of a number of the corpus is divisible by p it is divisible by p^2 at least. In this case then the lowest positive order number of a norm is 2. The degree of the cycle is 2 and the lowest possible positive order number of a number of the corpus for the cycle in question is 1.

When then p is an add prime of which Δ is a quadratic non-residue there is a single cycle of degree 2, order 1, and grade 2, corresponding to the prime and any number $R(\varepsilon)$ of the corpus will have a single p-adic order number corresponding to this prime, such order number being an integer, positive or negative, or 0.

Case III. In the case of the even prime 2 and Δ an odd number we know that there are solutions of the congruence

$$y^2 \equiv \Delta \pmod{2^k}$$

where $k \geqq 3$ when and only when Δ is of the form $8n + 1$. In this case we know that there are just two roots a and $-a \pmod{2^{k-1}}$ of the congruence.

When therefore $\Delta = 8n + 1$ there are two du-adic solutions of the equation

$$y^2 - \Delta = 0 \qquad (2).$$

Here then there are two cycles corresponding to the prime 2, each of these cycles being of the order 1. Where Δ has one of the forms $8n - 1$, $8n \pm 3$ the quadratic $y^2 - \Delta$ is irreducible in the du-adic field and there is only one cycle corresponding to the prime 2, this cycle being of degree 2. Considering the norm form $\dfrac{t^2 - \Delta u^2}{v^2}$ we see that for $\Delta = 8n - 1$, $\Delta = 8n + 3$ a norm may be divisible by 2 to the first power only, so that in these cases we have corresponding to the prime a single cycle of order 2, degree 2 and grade 1. Where Δ has one of the two forms here in question then any number $R(\varepsilon)$ of the corpus has a single order number corresponding to the prime 2, such order number being an integral multiple of 1/2.

Where $\Delta = 8n - 3$, it is evident that 4 is the lowest positive power of 2, which can be a factor of a norm. Consequently in this case the cycle of degree 2 is of order 1 and grade 2, and any number $R(\varepsilon)$ of the corpus will have a single order number corresponding to the prime 2 such order number being an integer, positive or negative, or 0.

Case IV. Here Δ is divisible by the prime p. Since Δ is not divisible by p^2 it is evident on the face of it that we can not solve $y^2 \equiv \Delta \pmod{p^2}$ and that therefore the quadratic $y^2 - \Delta$ is irreducible in the p-adic field. There is then only one cycle. The degree of this cycle is 2. Its order is evidently also 2, and its grade 1, since the norm Δ has the order number 1. This holds for the even prime 2 as well as for an odd prime.

To a prime factor p of Δ then there corresponds a single cycle of degree 2, order 2, and grade 1, and any number $R(\varepsilon)$ of the corpus will have a single order number corresponding to the prime p such order number being an integral multiple of 1/2.

With reference to the cycles and order numbers of numbers of a corpus for a prime p we may note that on selecting any primitive number ε of the corpus this determines an equation $f(x) = 0$ irreducible in the field of the rational numbers. It may be, however, that $f(x)$ is reducible in the field of the p-adic numbers, splitting up into a number of p-adically irreducible factors as in (7). In any arbitrary order we are free to call these the first, second, etc., ir-

reducible p-adic factors of $f(x)$ and to speak of the corresponding cycles as the first, second, etc., cycles for the prime p. Thereafter the order numbers of any number $R(\varepsilon)$ of the corpus correspond in a perfectly definite manner to these cycles, the form of $R(\varepsilon)$ determining the correspondence of the p-adic factors of $F(X)$ in (8) to the p-adic factors of $f(x)$ in (7). It might be that $R(\varepsilon)$ is itself a root of the equation $f(x) = 0$ other than ε, in which case the order numbers $\tau_1, \ldots, \tau_r$ of ε for the prime p would also be order numbers of $R(\varepsilon)$ but would in general correspond in some other order $\tau_\alpha, \ldots, \tau_\beta$ to the first, second, etc., cycles.

Considering a number of primes simultaneously we shall distinguish them by suffixes. If the number of cycles corresponding to a prime p_λ is designated by r_λ and the order numbers of a given number ϵ corresponding to the different primes $p_1 \ldots, p_\lambda \cdots$ be designated by

$$\tau_1^{(\lambda)}, \tau_2^{(\lambda)}, \cdots, \tau_{r_\lambda}^{(\lambda)}, \lambda = 1, 2, \cdots$$

and those of another number e of the corpus by

$$t_1^{(\lambda)}, t_2^{(\lambda)}, \cdots, t_{r_\lambda}^{(\lambda)}, \lambda = 1, 2, \cdots$$

the necessary and sufficient conditions for ε to be divisible by e, that is for ε/e to be an integral algebraic number, is given by the inequalities

$$\tau_\mu^{(\lambda)} - t_\mu^{(\lambda)} \geqq 0, \lambda = 1, 2, \cdots, \mu = 1, 2, \cdots, r_\lambda.$$

The order numbers τ and t here in question are integral multiples of the reciprocals of certain integers

$$\nu_1^{(\lambda)}, \nu_2^{(\lambda)}, \cdots, \nu_{r_\lambda}^{(\lambda)}.$$

In the field of the rational numbers we can always construct a number possessing as its order numbers an arbitrarily assigned set. This, however, is not the case with the numbers in any algebraic corpus which is more general than the field of the rational numbers. For example, we would not in general find in the corpus a number all of whose order numbers are 0 with the exception of a single coincidence $1/\nu$ corresponding to a definite cycle of a given prime p. Also a coincidence $1/\nu$ might be a constituent element in each of the order number sets of several integral numbers of the corpus no one of which could be factored within the corpus. These circumstances must have rendered futile any attempt to find in an algebraic corpus other than that of the rational numbers an analogue to the prime numbers in the sense of ultimate and unique factorization of the integral numbers of the corpus. The generalization from the factorization properties of rational numbers relative to the primes p lies rather in the extension of these properties as expressed in terms of prime order numbers to the properties of algebraic numbers in general as determined by their sets of p-adic order numbers. In the consideration of problems of factorization then the ultimate elements involved are the individual coincidences $1/\nu$ associated with the different cycles in the corpus.

In the light of what has been said in the preceding the conception of an ideal may be elucidated as follows: Assign an order number for each cycle corresponding to every prime p such order number being an integral multiple of the corresponding number $1/\nu$ and only a finite number of the order numbers being different from 0. The system of order numbers so assigned we shall designate by the notation (τ) and call a basis. A number of the corpus, we shall say, is built on the basis if no one of its order numbers is less than the corresponding order number furnished by the basis. The aggregate of the numbers of the corpus built on the basis (τ) we call an ideal. If none of the order numbers furnished by the basis is negative the ideal determined by the basis we call an integral ideal. If, apart from 0-order numbers, the basis (τ) consists of the single order number $1/\nu$ corresponding to a given cycle we say that the ideal determined by the basis is a prime ideal. A prime ideal then consists of all the integral numbers of a corpus whose order numbers for a certain cycle are $\geqq 1/\nu$ where ν is the order of the cycle in question. Where the basis (τ) consists of the actual order numbers of a number of the corpus the ideal determined by the basis is a *principal* ideal (Hauptideal).

What has been said in the foregoing with regard to the cycles of a quadratic corpus suffices to determine all the ideals in the case of such a corpus.

J. C. FIELDS

UNIVERSITY OF TORONTO

CONVERSATIONS WITH EUROPEAN MYCOLOGISTS[1]

DURING July and August of the present year, 1925, a botanical mission abroad was undertaken by the writers for the purpose of exchanging opinions with fundamental problems pertaining to the rusts (Uredinales). The project was heartily sponsored by the National Research Council, although efforts to partly or wholly finance the journey were fruitless, chiefly due to the brief interval after the plan was developed. The available time to be employed was necessarily limited, permitting but six weeks on European soil, and consequently it was only possible to visit Germany, Sweden, Norway, Denmark and En-

[1] Presented at the Kansas City meeting of the Mycological Section of the Botanical Society of America, December 30, 1925. Joint contribution from the Botanical Department of the Purdue University Agricultural Experiment Station and the Botanical Department of the Pennsylvania State College.

gland. Fortunately, we were able to meet most of the mycologists of these countries who have given marked attention to the rusts, especially in regard to their intimate structure, their modes of development and their relationships.

Our method of procedure was simple. Letters were sent a few days ahead announcing our coming and the purpose of our visit. The interviews were individual in each case, and occupied from two to four hours on an average. We had five or six typewritten articles with us, being the preliminary draft of two chapters of a forthcoming handbook of the rusts, one giving a brief synopsis and one the morphology and cytology; a restatement of a portion of the first chapter, together with the same in German; a much condensed statement of our views regarding rust development and the terminology required, couched in the shape of dicta; and a somewhat elaborated and changed form of the latter; all of which were considered by us to be of a tentative nature. These were used as a convenient basis for discussion and to expedite the presentation of our views, one or more being brought out each time as seemed best, the elaborated dicta most often of all.

There was no attempt at propaganda. What we desired was a frank expression of opinion regarding the deductions that may reasonably be drawn at the present time regarding the fundamental forms of the rusts, their general course of development and the terms best suited for indicating such conceptions. There has been, and still is, wide divergence of opinion regarding these matters. So far as the writers know, no one has ever before undertaken to compress these features into a statement that would include all forms and sorts of rusts, under all conditions of growth, and with absolutely no exceptions. We were bringing forward, therefore, a novel way of viewing the rusts, and naturally felt great uncertainty about the kind of reception such views were likely to meet, even presupposing the nationality of their advocates had no adverse influence.

In order that the reader may better understand the nature of the subject to which we were calling attention the dicta, as we used them, are here given, although it must be borne in mind that many other matters entered into the conversations, sometimes to the exclusion of the formal dicta. The other papers that we used are too long to be reproduced.

DICTA

Relating to life-cycles and sori of the rusts.

(1) The conception of rusts should first regard the vegetative body (mycelium) and secondarily the fruiting structures (sori) arising from it.

(2) The mycelium (usually uninucleate) possessing indications of ancestral sexuality, is regarded as gametophytic; the mycelium (usually binucleate) following in the same life-cycle, but discontinuous, is regarded as sporophytic.

(3) The long-cycle rusts have both kinds of mycelium; the short-cycle rusts have only gametophytic mycelium.

(4) The sori either produce spores exhibiting no or slight further development (pycnia), or they produce spores capable of definite growth and multiplication of cells (aecia, uredinia, telia, aeciotelia).

(5) The criteria for determining the morphologic and phylogenetic standing of the sori with efficient spores are:
  (a) The relation to the vegetative generation.
  (b) The relation to basidial production.

(6) The terminology of the sori with efficient spores and their distinguishing characters, based on this method, are as follows:

  I. *Aecia:*
    (a) The sori borne on the gametophytic mycelium.
    (b) The spores not directly producing basidia.
  II. *Uredinia:*
    (a) The sori borne on the sporophytic mycelium.
    (b) The spores not directly producing basidia.
  III. *Telia:*
    (a) The sori borne on the sporophytic mycelium.
    (b) The spores directly producing basidia.
  IV. *Aeciotelia:*
    (a) The sori borne on the gametophytic mycelium.
    (b) The spores directly producing basidia.

(7) There are structural characters useful in indicating the nature of sori but no such characters, single or combined, are sufficient to delimit any sorus, consequently, sori of wholly different origin may exhibit structural parallelism.

The subject was presented in more or less detail to Drs. Klebahn, Sydow, Kniep and Dietel, in Germany, Drs. Eriksson, Lagerheim and Juel, in Sweden, Dr. Jørstad, in Norway, Dr. Butler, Mr. Ramsbottom and Miss Wakefield, in England, and by a fortunate coincidence to Dr. Gäumann, of Switzerland. Many other botanists were met, with but slight opportunity, however, to discuss with them the purpose of our mission.

In every instance we were greeted with the utmost cordiality, and the object of our mission given respectful and unbiassed consideration. Every one, botanists and others alike, showed us courtesy, and there were no annoyances, wherever we went. We could discern no indication that nationality had any bearing upon the attitude with which our discussion was approached; in fact it was a surprise to find no trace of the jealousy and suspicion that in former

years was prevalent among botanists on the continent, and doubtless among students in other lines, causing much repression of their individual opinions and knowledge.

As it is clearly impractical for want of space to give an account of our interviews in detail, we must be content with a brief summary. It is to be understood that in this presentation we are not quoting actual statements, but rather expressing our conception of the opinions and beliefs of the various workers, based on our discussions with them.

In the first place there was practically uniform agreement that our statement respecting the development of the rusts, as shown in the dicta and their elaboration, was logical. Furthermore, the attempt to get a conception of rusts from the point of view of plant bodies was generally considered well worth while (Gäumann, Lagerheim). It is possible, we were told, to consider the basidiospores to be the most important spores in the life of the fungus, the aecia being the most important sori, and the other sori relatively unimportant (Jørstad), and that in such genera as *Coleosporium* there are no true teliospores, only groups of basidia (Gäumann, Jørstad). It was thought, however, that these matters do not materially affect the scheme we present, neither does the opinion that the rusts will eventually be found to be heterothallic (Kniep). Only once did we learn that somewhat similar views to ours regarding development had been entertained, and new terms devised to apply in part to the new concepts (Lagerheim).

It was almost unanimously agreed that the new terms we suggested followed naturally from our logic, but whether the terms were suitable or practical for general use was another matter that called out diverse opinions. There was no hesitancy to consider as a true aecium what in Germany and America is usually called the "primary uredo." It was pointed out in this connection that the term "primary uredo" is confusing, as it is often and more properly used to designate the first sorus following aeciosporic infection, which sometimes differs from the secondary uredinia that follow (Lagerheim, Butler).

There was practically uniform objection to the use of aeciotelium, partly because the term too strongly suggests Endophyllum, although admitting that the term is logically required (Klebahn, Ramsbottom), partly because all short-cycle sori can not be designated by a single term (Juel), and partly because the short-cycle sorus is apparently not materially different from long-cycle sori and so requires no separate term (Jørstad).

The terms employed should be adequate to express the ideas, we were told, even if new ones must be found (Gäumann), and we were materially assisted in one instance in devising new terms (Lagerheim), and yet usage can not be dictated (Butler).

As to adopting the terms pycnia, aecia, uredinia and telia in their own writings some offered no expression (Dietel, Gäumann), some thought the old terms could be modified or stretched to cover the new concepts (Klebahn, Juel, Wakefield), some were willing to employ them after they had been used in standard works (Sydow, Butler), others were inclined to put them into use soon (Jørstad, Lagerheim, Ramsbottom).

We did not go to Europe, however, to ask that our concepts or our terminology should be subscribed to or adopted, but to ascertain what our confreres would think about them, and if they had anything better to offer along these lines. What they have to offer will doubtless appear in due course of time. Our reaction to what they said has found expression in the following modified form of the dicta, which we believe is essentially in harmony with the views of our transatlantic coworkers among the rusts, whom we had the good fortune to meet.

REVISED DICTA

(1) The conception of rusts should give consideration both to the vegetative body (mycelium) and to the fruiting structures (sori) which arise from it.
(2) The vegetative body is either macrocyclic (long cycle), consisting of two unlike and discontinuous generations, or microcyclic (short cycle), consisting of one continuous generation.
(3) The fruiting structures, the sori, contain spores that are either inefficient, having no power to bring about infection, or efficient, having the power to bring about infection.
(4) The sori with inefficient spores (pycnia) are present or absent in both macrocyclic and microcyclic rusts, in the former only with the first generation.
(5) The sori with efficient spores in a macrocyclic rust are the initial forms (aecia) and final forms (telia), both essential, with or without intermediate repeating forms (uredinia); the sori with efficient spores in a microcyclic rust resemble either the macrocyclic aecia or telia, and may be designated by the same terms.

In conclusion we wish to express our appreciation for encouragement in undertaking the mission to members of the National Research Council, and other American friends. The cordial manner and frank cooperation of our European confreres made the mission a complete success. Any amount of correspondence, entailing much labor and time, could not have accomplished as satisfactory results. Not only has a better understanding between the workers in this field of science been established, but the general cause of science has been measurably advanced, and the feeling of international good will promoted.

J. C. ARTHUR
F. D. KERN

PURDUE UNIVERSITY
PENN. STATE COLLEGE

HERBERT FRANKLIN DAVISON

HERBERT F. DAVISON, assistant professor of inorganic chemistry at Brown University, suddenly stricken with a cerebral hemorrhage, passed away at his home in Providence, April 28, 1926.

Professor Davison was born in Pawtucket, R. I., in 1881. He was graduated from the Churchill grammar school in 1897, Pawtucket high school in 1901 and Brown University in 1905, subsequently receiving the master of arts degree from his alma mater. Since that time he was a teacher of elementary chemistry—first at a private school in Concord, Mass., and then for many years at the Pawtucket high school. There he was assistant principal when he resigned in 1918 to come to Brown, where he had charge of the courses in freshman chemistry.

He was a member of the University Glee Club, the Sigma Phi Epsilon fraternity, the Society of the Sigma Xi and the American Chemical Society.

In July, 1924, Professor Davison was married to Miss Daisy Capron, of Pawtucket, who was previously a teacher of domestic science in the Pawtucket high school. They made their home in the east side section of Providence.

As assistant professor of chemistry at his alma mater he won marked distinction as a demonstrator of the facts, utility and beauty of the science, and had the rare ability of exciting and sustaining in his students a love for scientific study. Many have been the careers in chemistry that had their beginning in his class room.

Professor Davison felt that teaching is one of the highest callings, and if enthusiasm, high ideals, command of his subject, hard work and ability to interest his students, are necessary in that calling, he certainly qualified as one of the best. He was perfectly happy when advising and helping his students, or when devising and trying out a new lecture table experiment to illustrate a principle in chemistry. At such demonstrations he was an adept, and many of his experiments with simple apparatus have been shown in his inimitable way to clubs and societies throughout New England. In this way he acquainted a large number of people with the meaning and workings of chemistry in daily life.

He worked just as hard and faithfully at his avocation—the growing of perfect apples. At his country home in Dudley, Mass., he had a splendid young orchard that gave him recreation and satisfaction in creative work.

One outstanding trait of his Christian character was positiveness. The doubting or negative side did not appeal to him. He was a positive ion, always charged, always pushing forward, always seeking the eternal truth. Stricken in the prime of life, in one short moment after a day of pleasant labor, he leaves a host of friends who deeply mourn his passing.

X

SCIENTIFIC EVENTS

THE SCIENCE EXHIBITION AT THE PHILADELPHIA MEETING OF THE AMERICAN ASSOCIATION

PREPARATIONS are in progress for the next annual science exhibition of the American Association for the Advancement of Science, which is to be an important part of the fifth Philadelphia meeting of the association, to occur next winter in convocation week, shortly after the close of the Sesqui-centennial celebration. It is planned that the main exhibition will be housed in the gymnasium of the University of Pennsylvania, in close proximity to the meeting places of the sections and societies. The registration offices and the offices of the publicity service for the meeting are to be in the same building, so that all who register, as well as the press representatives who attend the meeting, will find the exhibition conveniently located. It is hoped that the exhibition will be visited by every person in attendance at this meeting, which promises to be exceptionally large and comprehensive.

The exhibition will include recently developed scientific apparatus, materials and methods and recently published books in scientific fields. It is safe to predict that it will be even more successful than was the exhibition at the Kansas City meeting last year. The exhibits will be of three general kinds according to the method of entry: (a) commercial exhibits (including apparatus, materials and publications shown by manufacturers and dealers), (b) formally invited exhibits and demonstrations, from individual men of science and research laboratories and institutions, and (c) voluntary exhibits of non-commercial character contributed by individuals and research laboratories.

Assignments are now being made to commercial exhibitors, who will pay a reasonable charge in proportion to the space taken; inquiries and applications for space should be made as soon as possible to Major H. S. Kimberley, manager of the Philadelphia Exhibition of the American Association for the Advancement of Science, Smithsonian Institution Building, Washington, D. C. As at the Kansas City exhibition, the fees paid by commercial exhibitors are to go into a special exhibition fund from which all expenses of the main exhibition are to be paid. Remittances for space are to be made to the American Association for the Advancement of Science and the permanent secretary's office will keep the accounts and make all disbursements from the exhibition fund.

Prominent places in the exhibition will be given to the formally invited exhibits. It is hoped that this

feature will constitute a striking and representative demonstration of recent progress in the main scientific fields. Each section of the association is asked to make suggestions and recommendations as to the most important recent achievements in its field and invitations to individuals or laboratories will be issued from the permanent secretary's office after the suggestions have been examined and selections have been made by the committee on the Philadelphia exhibition. From the viewpoint of individual workers in scientific research this feature of formally invited demonstrations will be of paramount importance and it is specially necessary that well-considered section recommendations for the use of the exhibition committee be made just as promptly as may be. Each section secretary is asked to take up this very important matter with his section committee and to send the recommendations of the section to the permanent secretary's office before October 1. Suggestions as to possible invitations are requested from members of the association or of associated organizations; they should be sent to the proper section secretary or to the permanent secretary, who will forward them to the proper section secretary in each case. With adequate cooperation by men and women of science and by the section officers it will be possible for the invitations to be restricted to research workers or laboratories that have previously received recommendations from the sections. Of course the aim is to consider as possible exhibitors by formal invitation those who have recently made the most outstanding contributions to scientific progress.

Voluntary exhibits, of non-commercial character, will be accommodated as far as possible and no fees will be charged for their entry. Research institutions and individual scientific workers who are members of the association are asked, if they wish to take part, to make application for needed space just as soon as possible, addressing these applications to the permanent secretary. A concise and informing account of the proposed exhibit should accompany each application, stating the kind and nature of the objects to be displayed and the sort and amount of space required. The use of charts, diagrams and ordinary photographs, which require wall space and are not generally very attractive in an exhibition of this kind, should be avoided or restricted as far as possible, excepting in special cases. General attractiveness and scientific importance are both to be considered. Assignments of space for voluntary exhibits will be made by the exhibition committee about October 1 and all applications for space should be in the permanent secretary's hands considerably before that date. It is hoped that one or more exhibition prizes may be awarded to voluntary individual exhibitors whose contributions are of special merit.

The helpful cooperation of all association members and all members of other American scientific organizations, as well as others who are interested in the advancement of science and scientific education, will be needed in order that the Philadelphia science exhibition may be properly successful. The exhibition feature has gained remarkably in importance and value and attractiveness at recent annual meetings of the association and this development of association activity promises to continue. With the excellent and cordial publicity now given to the association meetings by the daily press throughout the country, the annual science exhibition bids fair to become very far-reaching in its influence.

BURTON E. LIVINGSTON,
Permanent Secretary

FIFTIETH ANNIVERSARY CELEBRATION OF THE FOUNDING OF THE JOHNS HOPKINS UNIVERSITY

PLANS for the celebration of the fiftieth anniversary of the founding of the Johns Hopkins University on October 22 and 23 have been announced. The main events of the celebration will be the dedication of the new $1,000,000 building of the School of Hygiene and Public Health, a series of conferences to be addressed by leaders in the social and natural sciences, exercises commemorating the fiftieth anniversary and an alumni banquet.

Representatives of England, France and Germany will take part in the celebration. Dr. Andrew Balfour, director of the London School of Hygiene and Tropical Medicine, will speak at the dedication of the School of Hygiene and Public Health Building. Professor F. Neufeld, of Berlin, director of the Institute for Infectious Diseases, will deliver the De Lamar memorial lecture. M. L. Levy-Bruhl, professor of the history of modern philosophy at the Sorbonne, is to make the principal address at the exercises commemorating the foundation of the philosophical faculty in 1876.

Newton D. Baker, former secretary of war; Edwin G. Conklin, professor of biology at Princeton University; Gordon J. Laing, dean of the graduate school of arts and literature at the University of Chicago, and Charles R. Bardeen, dean of the medical school of the University of Wisconsin, will be the speakers at the alumni banquet.

Dr. Ira Remsen, the only survivor of the seven professors who were members of the faculty when the university was opened in 1876, will attend the celebration. He was the first professor of chemistry and the second president of the university. William M. Burton, president of the Standard Oil Company of Indiana, one of Dr. Remsen's students in the early

days of the university, will deliver the address of welcome in his honor.

Plans are being made along the lines similar to those of the meetings of national scientific and learned societies for a series of sixteen conferences in the main branches of learning. Among the Johns Hopkins alumni who have already consented to speak at these conferences are:

Henry Van P. Wilson, professor of biology, University of North Carolina.

Ross G. Harrison, professor of anatomy, Yale University.

W. C. Coker, professor of botany, University of North Carolina.

Joseph Jastrow, professor of psychology, University of Wisconsin.

Edward C. Franklin, professor of organic chemistry, Leland Stanford University.

William H. Burnham, professor of pedagogy, Clark University.

William S. Bayley, professor of geology, University of Illinois.

Florence Bascom, professor of geology, Bryn Mawr College (first woman to receive the degree of Ph.D. at the Johns Hopkins University).

George Otis Smith, director of the Geological Survey.

Benjamin Leroy Miller, professor of geology, Lehigh University.

D. W. Ohern, formerly professor of geology in the University of Oklahoma.

Marcus I. Goldman, of the Geological Survey.

W. P. Woodring, of the Geological Survey.

Luther P. Eisenhart, professor of mathematics, Princeton University.

Arthur B. Coble, professor of mathematics, University of Illinois.

Henry B. Brooks, chief of the electrical instruments and meter section of the United States Bureau of Standards.

A SURVEY OF FORESTRY RESEARCH UNDER THE NATIONAL ACADEMY OF SCIENCES

PROFESSOR HENRY S. GRAVES, dean of the School of Forestry and provost of Yale University, will spend the summer at various European forest schools and experiment stations making a study of the educational aspects of the problems of research in forestry, with special reference to the requirements for training men to conduct research in this field.

Dean Graves is a member of a committee of three engaged in making an intensive study of research problems in forestry, conducted under the auspices of the National Academy of Sciences and financed by the General Education Board. This is said to be the first time that American natural scientists have intensively investigated European methods of preserving the forests with a view to their application in the United States.

The purpose of the study, according to Dean Graves, is to determine what are the important lines of basic research necessary to lay a sound foundation for forestry, to ascertain what is now being done in this country and abroad, and to formulate a plan for a greatly enlarged program of research.

"A certain amount of research," he said, "is now under way at the various stations of the United States Forest Service, at the forest schools and at various other agencies and institutions. There is, however, special need of investigations in the sciences underlying forestry with special reference to problems encountered in the field of forestry. The National Academy is particularly interested in these fundamental problems."

The special committee under whose direction the work will be accomplished consists of the chairman, Professor L. R. Jones, of the University of Wisconsin, Dr. John C. Merriam, president of the Carnegie Institution of Washington, who also represents the academy, and Dean Graves. The actual work of making the survey of the problems of research will be carried on by Professor I. W. Bailey, of the department of botany of Harvard University, who for a long time has been associated with the forestry work done at that institution, and by Dr. H. A. Spoehr, head of the laboratory of the Carnegie Institution at Carmel, Calif.

APPOINTMENT TO THE NON-RESIDENT LECTURESHIP IN CHEMISTRY AT CORNELL

THE non-resident lecturer in chemistry at Cornell University for the first term of the next university year will be Dr. Fritz Paneth, professor of inorganic chemistry in the University of Berlin, who will present, under the general title "Selected Topics in Inorganic Chemistry," the results of his research and study concerning the general significance of radiochemistry, isotopes, the periodic system from the viewpoint of Bohr's atomic theory, the hydrogen compounds of the chemical elements, natural and artificial transformation of the elements, and the use of the radio-elements as indicators.

A correspondent writes that although only thirty-eight years of age, Professor Paneth has already achieved international reputation as one of the most brilliant and versatile investigators in his field. He is an Austrian, and his student years were spent in his native city, Vienna. He received the degree of doctor of philosophy from the University there in 1910, and then was appointed assistant in the Vienna Radium Institute. In 1913 he went to Great Britain and studied under Soddy in Glasgow and Rutherford in Manchester. Upon his return to Vienna he received appointment as instructor (privatdozent) in

inorganic chemistry and radioactivity in the university of Vienna. He was then called to the German Technical School in Prag, and in 1919 accepted a professorship in the newly created University of Hamburg. In 1922 he received appointment to the professorship of inorganic chemistry in the University of Berlin, the position which he now holds.

SCIENTIFIC NOTES AND NEWS

DR. CALVIN W. RICE, secretary of the American Society of Mechanical Engineers, has received the degree of doctor of engineering from the Technische Hochschule of Darmstadt. Dr. Rice is now visiting technical and industrial museums in Europe.

DR. JABEZ N. JACKSON, president of the American Medical Association, has received the honorary degree of doctor of science from Park College.

QUEENS UNIVERSITY, Kingston, Ontario, Canada, conferred the honorary degree of LL.D. on Dr. William H. Rankin, officer in charge of the Dominion Laboratory of Plant Pathology, on May 6, who graduated from that institution thirty-seven years ago.

PROFESSOR LUCIEN GALLOIS, of the University of Paris, was presented with the Cullum geographical medal by Ambassador Herrick on May 27. This medal was awarded to Professor Gallois last December by the American Geographical Society for his work in the advancement of geography.

AMBASSADOR J. G. SCHURMAN has arrived in Munich for the purpose of presenting the David Livingstone centenary medal of the American Geographical Society recently awarded to Professor Erich von Drogalski in recognition of his work in the South Polar region.

AT the fourth annual meeting of the Virginia Academy of Science, held at the University of Virginia on May 7 and 8, Dr. J. Shelton Horsley was elected president and Dr. E. C. L. Miller, secretary-treasurer, both of Richmond, Va.

DR. GEORGE B. FRANKFORTER, professor of chemistry and for many years dean of the school of chemistry at the University of Minnesota, will retire at the close of the current academic year, after thirty-three years of service.

DR. WILLIAM H. BURNHAM, for twenty years head of the department of pedagogy and the school of hygiene of Clark University, will retire from his professorship at the end of the present university year.

THE fiftieth professional anniversary has recently been celebrated by the emeritus professors, H. Vierordt, Tübingen; M. von Gruber, Munich, and P. Zweifel, Leipzig.

ROBERT T. BOOTH was succeeded on April 1 by Richard H. Goddard as observer-in-charge of the Huancayo Magnetic Observatory (Peru) of the Carnegie Institution of Washington.

GEORGE W. SEARS, of the chemistry department at the University of Nevada, has been appointed consulting chemist in the rare and precious metals, at the Reno Experiment Station, of the Bureau of Mines.

N. A. C. SMITH, assistant superintendent of the Petroleum Experiment Station of the U. S. Bureau of Mines, at Bartlesville, Oklahoma, has been appointed superintendent of the station. He succeeds E. P. Campbell, who recently resigned to accept a position with the Pure Oil Company.

PROFESSOR LEONOR MICHAELIS, of the University of Berlin and visiting professor of biochemistry in the Aichi University of Nagoya, Japan, has been appointed resident lecturer in research medicine in the Johns Hopkins University for a period of three years. Dr. Michaelis has recently arrived from Japan and has begun his research work in biophysics at the Johns Hopkins Hospital.

ASSISTANT PROFESSOR CHARLES E. O'ROURKE, of Cornell University, has been granted a leave of absence for at least one year to accept a position as head of the department of structural engineering at Peiyang University in Tientsin, China. He will sail on July 15.

PROFESSOR F. L. WASHBURN, of the University of Minnesota, has returned from the South Pacific with several thousand insect specimens for his institution. Collections were made chiefly in the Tuamotu Archipelago and in the Leeward group of the Societies.

DR. JOHN K. SMALL, head curator of the New York Botanical Garden, has been engaged in botanical exploration in southern Florida and Louisiana.

C. T. GREENE, assistant entomologist in the taxonomic investigations, U. S. Bureau of Entomology, has gone to Panama, where he will collect, rear and associate larvae and adults of fruit flies for the Federal Horticultural Board.

DR. TRUMAN MICHELSON, of the U. S. Bureau of Ethnology, left Washington on May 30 for the Fox reservation at Tama, Iowa, to spend his fifteenth consecutive season of research work with the Fox tribe of Indians.

PROFESSOR MARCUS C. FARR, of the department of geology at Princeton University, will sail for England on June 24 for study at the British Museum.

PROFESSOR F. L. STEVENS, of the University of Illinois, will spend the summer studying type speci-

mens of fungi, mainly in Paris, Berlin, Brussels and London, and will read a paper to the British Association for the Advancement of Science.

DR. LEON VELASCO BLANCO, of the University of Buenos Aires, visited the University of Minnesota in April to arrange for an exchange of professors of the medical schools of the two universities for next year.

PROFESSOR J. SCHMIDT, director of the Carlsberg Laboratory in Copenhagen, is in the United States on his way home to Copenhagen after several months spent in the South Pacific studying the migration habits of eels. Professor Schmidt is giving a lecture at the Smithsonian Institution on June 4.

AT the University of Washington, on May 4 and 5, Professor R. A. Millikan delivered three addresses. On the evening of May 4 he spoke on "The Nature of Radiation," in the forenoon of May 5 on "The Constitution of Matter" and in the evening of the same day on "The Birth of Two Ideas." The last lecture was the annual joint address of the University of Washington chapters of Phi Beta Kappa and Sigma Xi.

AT the regular meeting of the New York University chapter of Sigma Xi, held at the Faculty Club, University Heights, on May 21, Dr. John C. Merriam, president of the Carnegie Institution, delivered a lecture on "The Meaning of Evolution in Individual Experience."

DR. MICHAEL I. PUPIN, professor of electromechanics at Columbia University, will be the principal speaker at the graduation exercises at the Massachusetts Institute of Technology on June 8.

DR. MARTIN H. FISCHER, head of the department of physiology, University of Cincinnati College of Medicine, will deliver the address at the graduating exercises of the University of Tennessee College of Medicine on June 7.

DR. RALPH W. CHANEY, research associate in paleobotany, Carnegie Institution, gave a public lecture at the Carnegie Institution on May 25 on "World Migration as illustrated by Distribution of the Redwood Tree."

DR. WALTER TIMME, clinical professor of neurology in Columbia University College of Physicians and Surgeons, recently gave the Emmerling Memorial Lecture before the Pittsburgh Academy of Medicine on "The Nature, Character and Treatment of Pituitary Migraine."

DR. R. W. HEGNER, professor of protozoology in the Johns Hopkins School of Hygiene and Public Health, presented an address on the "Biology of Host-Parasite Relationships among the Protozoa" at a meeting of the Royal Society of Medicine, London, on May 13.

PROFESSOR ERNST COHEN, director of the Van't Hoff laboratories at the University of Utrecht, gave an address on May 29 on the "Metamorphosis of Matter and the Allied Alleged Constancy of our Physico-Chemical Constants," before a joint meeting of the Washington Academy of Sciences, the Philosophical Society of Washington and the Chemical Society of Washington, at the Cosmos Club.

DR. FRANK NELSON COLE, professor of mathematics at Columbia University since 1895 and secretary of the American Mathematical Society for twenty-five years, died on May 26, aged sixty-five years.

DR. HENRY SKINNER, vice-president of the Philadelphia Academy of Natural Sciences, entomologist and physician, died on May 30, aged sixty-five years.

DR. RICHARD W. HICKMAN, a former division chief in the U. S. Bureau of Animal Industry, died on April 30, aged seventy-four years.

APPLICATIONS for fellowships in medicine of the National Research Council, in order to receive consideration at the September meeting of the medical fellowship board, should be filed on or before August 1. Communications should be addressed to the chairman of the Medical Fellowship Board, National Research Council, Washington, D. C.

THE United States Civil Service Commission announces an examination for senior ordnance engineer (projectile and bomb), receipt of applications for which will close on June 22. The examination is to fill a vacancy in the Ordnance Department at large, Picatinny Arsenal, Dover, N. J., at $5,000 a year, and vacancies occurring in positions requiring similar qualifications.

THE Iowa Academy of Science convened in its fortieth annual meeting at Coe College, Cedar Rapids, Iowa, on April 30 and May 1, 1926. There were 200 in attendance at the meetings, and 184 papers were presented. The presidential address, "The Ministry of Science," was delivered by Mr. R. I. Cratty, curator of botany and the museum, Iowa State College. Dr. Joel Stebbins, of the Washburn Observatory, University of Wisconsin, addressed the academy at a public lecture, "The Twinkling Stars." Officers were elected as follows: *President,* C. E. Seashore, State University; *vice-president,* L. D. Weld, Coe College; *secretary,* P. S. Helmick, Drake University; *treasurer,* A. O. Thomas, State University; *editor,* Willis DeRyke, State University; *representative* to the American Association for the Advancement of Science, D. W. Morehouse, Drake University.

THE Sigma Gamma chapter of Sigma Pi Sigma, national physics fraternity, was formally installed at Pennsylvania State College on May 17. Professor W. W. Wood, of the Sigma Alpha chapter at Davidson College, was in charge of the installation. The chapter has eighteen charter members.

CUMMINGS C. CHESNEY, manager and chief engineer of the General Electric Company's works at Pittsfield, Mass., was, in accordance with the membership ballot by mail ratifying the directors' nominees, elected president of the American Institute of Electrical Engineers at the annual business meeting held in the Engineering Societies Building, New York, on May 21. Other officers elected were: *vice-presidents,* H. M. Hobart, Schenectady, N. Y.; George L. Knight, Brooklyn, N. Y.; B. G. Jamieson, Chicago; A. E. Bettis, Kansas City, Mo.; H. H. Schoolfield, Portland, Ore.; *managers,* F. J. Chesterman, Pittsburgh; H. C. Don Carlos, Toronto; I. E. Moultrop, Boston; *treasurer,* George A. Hamilton, Elizabeth, N. J. (reelected).

ACCORDING to the *Electrical World,* Professor Harold B. Smith was the toastmaster at the banquet of the regional gathering of the American Institute of Electrical Engineers at Niagara Falls. The chief speaker was Edward D. Adams, who spoke on "The Pioneer Development of Hydro-electric Power at the Cataract." Mr. Adams was preceded by seven speakers, these being Paul A. Schoellkopf, president Niagara Falls Power Company; President Pupin, former President Osgood, former Vice-president Faccioli, Secretary Hutchinson, Vice-president-elect Hobart and President-elect Chesney, of the institute.

AN institution similar to Science Service of Washington, for the purpose of supplying to the press readable and reliable knowledge of scientific progress, has been formed in Paris under the title of "Office d'Information Scientifique et Technique," at the instigation of M. le duc de Gramont. The board of control consists of J. L. Breton, director of the National Office of Scientific and Industrial Research and Inventions; Charles Fabry, professor at the Sorbonne and Polytechnic School; Armand de Gramont, president of the council of the Institute of Optics; Paul Janet, director of the Superior School of Electricity; Louis Lumiere, of the Academy of Sciences; Louis Mangin, director of the Museum; Emile Picard, permanent secretary of the Academy of Sciences; Georges Roger, dean of the faculty of the Academy of Medicine; Emile Roux, director of the Pasteur Institute. The director of the office is Lt.-Colonel J. Raibaud. The new institution will cooperate with Science Service of Washington in the exchange of news of scientific and industrial progress in France and the United States.

A FELLOWSHIP of $1,000 for a Swedish student to study one year in an American university or technical school as a memorial to John Ericsson, inventor of the screw propeller and of the Civil War craft *Monitor,* has been established, according to an announcement by the American-Scandinavian Foundation. The fellowship is given by the John Ericsson Society of Engineers in New York and the selection will be made by a jury acting for the foundation in Stockholm. A similar $1,000 fellowship has been given by Captain A. P. Lundin, New York, president of the John Ericsson Society, for an American student to be sent to a Swedish university for the year 1926–27. This is in addition to twelve similar fellowships recently awarded by the foundation to American students for graduate work in Sweden, Norway and Denmark. The Ericsson monument was unveiled in Washington on May 29 by the Crown Prince of Sweden and President Coolidge. As the granite has not yet been completely carved only the plaster model has been put in place. Three figures, Invention, Adventure and Labor, rise above the seated figure of Ericsson, who is represented as though deep in thought.

MAJOR MARTIN J. CONNOLLY, of Washington, D. C., has given $15,000 to Saint Louis University to build and equip a first-class seismographic station for the study of both local and distant earthquake shocks.

STANFORD UNIVERSITY MEDICAL SCHOOL recently received $1,000 from Dr. Morris Herzstein for the establishment of a lectureship on the diseases of the Pacific Basin.

UPON the recommendation of the Finnish Academy of Science, the government of Finland has made an official grant of 5,000 marks towards the maintenance of the international periodical for psychology, *Scandinavian Scientific Review,* edited by Dr. Martin L. Reymert, aided by an advisory board in each of the Scandinavian countries.

JULIUS ROSENWALD, of Chicago, who has been touring Europe to get ideas for an industrial museum in Chicago, has donated $5,000 to the Deutsches Museum of Munich.

THE medical school of St. Thomas's Hospital, London, has received a gift of £15,000 from the Rockefeller Foundation towards the building of new laboratories for the use of students. The laboratories will be situated within the hospital and will be easily accessible from the wards.

THE public bill committee of the Quebec legislature assembly has favorably reported a bill to incorporate the Association of Professional Chemists of Quebec, according to the *Journal* of Industrial and Engineering Chemistry. This bill provides that only members of the association will be entitled to use the

term "professional chemist," the restriction to become effective on September 1, 1926. This act will not prevent others from practicing the profession of chemistry, so long as they do not endeavor to use the title "professional chemist." An amendment to the original bill provides that nothing in the new legislation shall be interpreted as affecting the rights and privileges granted to the members of the corporation of professional engineers of Quebec, those who hold diplomas issued by the Montreal Polytechnic School or by the faculty of applied science of McGill University, those who have a diploma of pharmacy or medicine, or members of the two latter professions who shall be allowed as in the past to practice chemistry under whatever name they wish, provided they do not take the title "professional chemist."

ACCORDING to the *Electrical World* the Swiss national committee of the World Power Conference, with the permission of the international executive conference, will hold a sectional meeting in Basle, Switzerland, this year from August 31 to September 12. European countries have been asked to participate in an organized way. Other countries have been invited to have representatives in attendance, and papers submitted through their national committees will be incorporated in the proceedings. O. C. Merrill, the chairman of the American national committee, has not determined as yet whether it will be possible to submit a national paper to this conference. The main subjects to be considered embrace railway electrification, electricity in agriculture, exchange of electrical energy between countries, utilization of water power and inland navigation, and the economic relation between electrical energy produced hydraulically and that produced thermally.

UNIVERSITY AND EDUCATIONAL NOTES

IT is announced that a chemistry building costing $1,200,000 will be erected with a portion of the $20,000,000 fund now being raised by Princeton University. The building will be in the collegiate Gothic style to harmonize with other buildings recently constructed.

CONSTRUCTION of the new chemistry building to be erected at the University of Maryland will begin almost immediately. The entire sum appropriated by the state legislature ($210,000) will be employed in constructing the building itself. Sums necessary to equip the various laboratories have been donated by Dr. and Mrs. M. L. Turner, of Berwyn, Maryland; Dr. H. A. B. Dunning, of Hynson, Westcott and Dunning; Dr. Samuel W. Wiley, of Wiley and Co. Inc., and the Alumni Association of the university. The new building will be ready for occupancy February 1, 1927.

A CAMPAIGN is in progress to raise an endowment fund for the Medical College of the State of South Carolina under the chairmanship of Dr. D. Lesesne Smith, Spartanburg. An organization is to be formed in every county in the state.

DR. WILLIAM LORENZO MOSS has been appointed acting dean for the first half of the year 1926–27 and assistant dean for the second half of the year in the school of public health at Harvard University.

DR. FREDERICK L. REICHERT, of the Johns Hopkins University Medical School, has been appointed associate professor of surgery in the Stanford University Medical School.

AT Yale University Dr. John Spangler Nicholas, assistant professor of anatomy at the University of Pittsburgh, has been appointed assistant professor of biology and Dr. Arthur Edward Ruark, of the U. S. Bureau of Standards, assistant professor of physics.

ROBERT F. FIELD, instructor in physics at Harvard University, has been appointed assistant professor of applied physics.

DR. C. R. MEGEE has been appointed acting professor of agronomy in the college of agriculture of Rutgers University.

PROFESSOR JOHN A. FERGUSON, head of the department of forestry at Pennsylvania State College, has been named visiting professor of forestry at Yale University for 1926–27. Professor Ferguson will take over the work in forest management while Professor Herman H. Chapman is on leave to participate in a government investigation of forest taxation which is being conducted by Professor Fred R. Fairchild, of Yale.

DISCUSSION AND CORRESPONDENCE

WHY THE TEMPERATURE OF THE AIR DECREASES WITH INCREASE OF HEIGHT

THE decrease of atmospheric temperature with increase of height is a phenomenon of unusual philosophic fascination, if one may so infer from the frequent explanations he sees of it, and from the further fact that nearly always these "explanations" are either utterly erroneous, or, at best, wholly inadequate. And the pity of it is that some of the worst of these come from high authorities, through hasty or heedless writing, for surely they know better.

One eminent scientist, in a great treatise now appearing, explains this decrease of temperature with

increase of height as being due to the accompanying decrease of density—the lighter or upper air not being able to hold so much heat as the lower and heavier air. Presumably heat capacity per unit volume is meant, but it is not so stated; neither is any attempt made to tell why this decrease of heat capacity should lead to a decrease of temperature. This is unfortunate, for such an attempt would have ended in complete failure, and shown at once how utterly erroneous the given explanation really is. For instance, it implies that the rarer the atmosphere the lower its temperature, indefinitely, a conclusion flatly contradicted by numerous aerological observations begun more than a quarter of a century ago and continued every year since then.

Another eminent scientist in a delightful book just published says that this paradox is the easiest sort of thing to explain—that it is all because the air is very transparent. This is nice enough so far as it goes, but it leaves the reader to supply nine tenths of the reasoning, and to find, if he can, why the atmosphere instead of always growing colder and colder with increase of transparency, that is, in general, with increase in height and rarefaction, as this theory indicates it must, cools only to a limited extent.

Obviously, then, the correct explanation of this phenomenon, although well known, is not widely known, and therefore needs to be published in a conspicuous place, and restated in some form every now and then until eventually it becomes securely fixed in scientific literature.

The essentials of this explanation are as follows—tediously numerous and detailed for any one who really knows the subject, but because of such detail all the more helpful to some who may not yet fully understand it:

(1) A considerable portion, actually between one fourth and one third, of the solar radiation incident on the outer atmosphere, gets through to, and is absorbed by, the surface of the earth.

(2) A roughly equal portion is directly taken up by the air, owing mainly to the presence of water vapor and carbon dioxide, and, when there are no intercepting clouds, generally in increasing amount per unit mass with decrease of height.

(3) Radiation from the surface of the earth also is strongly absorbed by water vapor and carbon dioxide, hence, as a rule, decreasingly absorbed per unit mass of air with increase of height.

(4) Clearly, then, through absorption of radiation and by conduction from the earth, the surface air is more heated and thereby raised to a higher temperature than that of any other level.

(5) Owing to its expansion with increase of temperature, and to the irregularities of surface heating, the lower air here and there becomes lighter than that immediately adjacent to it, by which it therefore is pushed up much as a cork is pushed up when let go under water, or a balloon when set free. It does not rise of its own accord, as it were, or by virtue of some strange levitation as it usually is said to do. It is forced up.

(6) With increase of height the pressure per unit area becomes less and less by the weight of the air left below in a vertical column of unit cross-section.

(7) As the pressure decreases the rising mass of air expands, but always against the then remaining pressure, and thereby does work.

(8) This work is at the expense of the energy of the expanding air—the heat it contains. That is, the rising air expands against the current pressure, thereby doing work at the expense of its own heat and, in consequence, growing colder with increase of height.

This in substance is the end to the most elaborate explanation one commonly sees of the cause of the decrease of temperature with increase of height. But according to it, no limit is set to the surface temperature nor to the height of convection except, infinitesimally, that which would be sufficient to cool the rising air down to the absolute zero. Yet we know that the temperature of the surface does not increase indefinitely, and that convection is limited to a comparatively low level, and cooling to a corresponding moderate degree. All these limitations result from the fact that the air not only absorbs radiant energy but also emits it.

Now, the efficiency of an object as an absorber of radiation of a given kind, or wave-length, depends on its nature and not upon its temperature, while its rate of giving out radiation decreases very rapidly with decrease of temperature.

(9) Evidently, therefore, the normal limit to which warmer air at the surface or any other level can eventually cool by convection is that temperature at which it loses as much heat by radiation as it absorbs.

On the whole, then, the surface air is gaining heat and the free air losing heat so long as its temperature is greater than that which gives the radiation equilibrium mentioned above. In short, all the atmosphere under this equilibrium ceiling (roughly seven to fifteen kilometers above sea level, according to latitude) is being heated below, especially at the surface, and cooled above. By this means mainly, and partly by the turbulence of the winds, vertical convection of this portion of the atmosphere and its consequent decrease of temperature with increase of height are perpetually maintained.

To sum up: The decrease of the temperature of the air with increase of height is owing to its dynamic

cooling incident to convection which, in turn, is maintained by warming below and cooling above, the warming by absorption and conduction, the cooling by radiation.

W. J. HUMPHREYS

U. S. WEATHER BUREAU

CONCERNING AUTHORITY AND THE SCIENTIFIC METHOD

I HAVE received the following letter from the dean of the University of Mississippi School of Medicine, dated March 2, 1926:

Dear Professor Linton:—

I notice in your address as retiring vice-president of section F—Zoology—American Association for the Advancement of Science, which is reported on p. 199 of SCIENCE for February 19, you make the following statement: "If the timorous defenders of authority at Baylor, Denison, Mercer Universities, and the Universities of Mississippi and Tennessee found the professors whom they recently dismissed guilty of showing Professor More, or any one else an amoeba with. . . ."

In so far as the University of Mississippi is concerned, I am glad to advise that no one has been dismissed in the last thirty-five years for any such reason as you give. I haven't investigated any farther back than this. I shall be glad if you will make this correction in SCIENCE.

Yours very truly,
J. O. CRIDER, Dean

Upon looking up the letter from which I had quoted from memory when writing the paragraph in question, later referring to it simply to see that I had the names of the institutions as they were named therein, I find that it reads thus (names of the professors being omitted in this copy):

Among those who are said to have been the victims of this anti-evolution movement, are Dr. ———, Professor of Zoology, University of Mississippi; Dr. ———, Professor of Sociology, Baylor University, Waco, Texas; Dr. ———, Professor of Zoology, Denison University, Granville, Ohio; Professor ———, University of Tennessee.

The letter was dated October 21, 1924. The name of Mercer University was my own contribution to the list. My habitual inclination, when fully awake to the possible importance of the occasion, is to pluck feathers from the wings of passing rumor, rather than to assist her on her devastating flight. It is therefore with a chastened spirit that I note in this instance the unpleasant fact that I have apparently, but I can assure Dean Crider, quite unintentionally, added a feather to her pinions, seeing that my words are "the professors whom they recently dismissed"; whereas my authority, for all except the Mercer case, uses the phrase: "Among those who are said to have been the victims, etc."

If I had had it in mind to discuss that disagreeable topic, the dismissal of college and university professors, I should, of course, have been careful to verify my data. Since my object was a quite different one, I trust that I have made the proper amend.

I am glad to be able to add a further good word for the University of Mississippi. I have a letter, dated March 18, inst., from my friend who was named as the one who was reported to have been dismissed from the University of Mississippi as a result of the anti-evolution movement, from which I quote:

You can make the following statement: During my stay at the University of Mississippi I taught evolution to my classes and as a consequence became aware of considerable criticism of myself for so doing. These criticisms originated outside of university circles. The attitude of the people of Mississippi with whom I came in contact, however, was never hostile and unfriendly in a personal way. I was treated with great courtesy. No official at any time threatened to have me discharged for my teaching. . . . I should add that this popular criticism of me in Mississippi became so strong that it occasioned considerable *concern* on the part of one of my superiors, though this man never threatened action against me.

If there exists in any minds the belief that demonstrated truths concerning the operations of nature have been withheld from the students at the University of Mississippi, I am glad to aid in dispelling that misapprehension.

But back of every silver lining there lowers the inevitable cloud. Thus it has come about that while the correspondence was in progress which supplies the subject-matter of this communication, there appeared the following note in SCIENCE, March 5, inst., (p. 253):

The bill to prohibit teaching in tax-supported schools the theory that man "ascended or descended from lower animals" was passed by the Mississippi Senate February 24, 29 to 16, after three hours debate. The bill was passed by the House of Representatives on February 8, by a vote of 76 to 32.

This bill has been signed by the governor of Mississippi and is now a law of the state.

The following extract from an editorial in *Nature*, February 13, ult., is commended to the consideration of those twenty-nine Senators and seventy-six members of the House of Representatives of Mississippi who appear to be of those who "would mould the

modern mind after the pattern of an age unlearned in the interpretation of nature."

> The gradual diffusion in the American religious public of more enlightened views about the Bible and the course of history may be trusted, therefore, to make the present attitude a passing one. The very concentration of attention upon the subject must have this effect. By staking their whole position on the verbal inspiration and inerrancy of the Biblical canon, the Fundamentalists will very soon be found to have engineered their own defeat. . . .
>
> It is no longer a struggle between men of science and theologians as such, for the foremost theological teachers of the day are as penetrated by the scientific and historic spirit as any man of science in the ordinary sense of that term. It is in reality a struggle in common against the miserably defective culture of great masses of our population (p. 222).

The Mississippian, March 12, 1926, contains a letter written by Chancellor Alfred Hume, of the University of Mississippi, to Governor Whitfield urging him to veto the anti-evolution bill. The letter is a dignified and able discussion of this anti-science legislation from the point of view of a man who is manifestly, in the highest sense, qualified to testify to the truth which is fundamental to science whether dealing with physical, ethical or religious questions. Following is a brief extract from the letter:

> In case the measure to which I refer become a law, quite a number of our faculty will be confronted with a cruel ethical dilemma. Either they will have to evade, disregard, or openly violate the law, or, else, they will have to be guilty of intellectual dishonesty. To any one at all worthy of his position on our faculty both of these courses are unthinkable and intolerable.

It is not a promising outlook which is foreshadowed when the lawmakers of a state turn aside from the leadership of those who know to follow the will-o'-the-wisp of ignorance.

These 105 Mississippi lawgivers might profitably reflect on what a Georgia farmer remarked to a physician acquaintance of mine here in Augusta a few days ago: "Doc, what this country's a sufferin from is ignor*ance*."

I shall close this communication with a bit of personal experience.

During the past four years my home has been in this beautiful southern city. Among my habits, commendable and otherwise, is that of going to church once on Sunday. Such has continued to be my practice here in Augusta. In all the sermons which I have heard since coming here there has been allusion to the present anti-science agitation in but one of them. That was before the Dayton trial took place. The clergyman characterized the then recently enacted anti-evolution legislation in Tennessee as the product of "an infantile view of science and a senile view of theology."

EDWIN LINTON

1104 MILLEDGE ROAD,
AUGUSTA, GA.

THE MASTER'S DEGREE AND SCIENTIFIC RESEARCH

READERS of SCIENCE may be interested in observing the trend of the encouragement given research in so far as such is a requisite for the granting of the master's degree. The data given in this summary were obtained for the most part from questionnaires sent to all the state universities and other leading institutions and has been supplemented through the study of the catalogues of certain colleges.

Sixty-three institutions in all were considered. Of these, thirty definitely indicate that research is required for the master's thesis in science; two others insist upon it in certain departments only, while nine have no preference between research and other types of material submitted in theses. The remaining ones, while of course accepting research, do not feel it is necessary, and so do not insist upon it. As might be expected, the most extensive association of research with the degree is found in the universities, where twenty-nine institutions require it, as against seven which do not. The theses may or may not involve research at ten of the remaining universities, while eight give no information whatsoever as to the kind of work required in the thesis. Of the ten colleges considered, four favor research for the degree under certain conditions, five do not, while one does not state its attitude.

From the educational standpoint there lie at the bases of these preferences interestingly different conceptions of the significance of the master's degree. Twenty institutions regard it as specific preparation (in the sense of mastering the technique of investigation, etc.) for the Ph.D. degree, five others stating that they regard it as a "little doctorate." On the other hand four as expressly state that they do not regard it in the latter sense, while as many feel in addition that the required intellectual ability to be expressed in the thesis need only be that necessary for the interpretation of facts already known. In this sense, then, "original work" is differentiated from research. More or less allied with the feeling that research need not be allied with the master's degree are the following conceptions of it. Eight consider it a degree for teachers (presumably for secondary schools or smaller colleges); seven merely as an advancement of undergraduate scholarship, or as accomplishing a year of graduate study; four believe it to be the degree for those who can not

devote a greater period of time to the work, while three conservatives prefer to view it as the balm for the doctorate candidate who is to be discouraged. Some readers may feel that the master's degree at present, as well as in past years, is largely meaningless. To the writer, however, the intergrading viewpoints expressed above as to the functions and requirements of the degree are in part at least responses to the prevailing atmosphere of the institutions granting them, and the largely local demands they feel they must meet. This is especially true of the colleges which have the troublesome care of graduate assistants.

As regards the time required in residence for completion of the requirements of the degree, sixty-one institutions indicate one year as the minimum period of study, while but two require two years. Thirty-one believe that the period of study should be prolonged beyond the normal time and generally to a period of two years in the case of assistants in instruction. Three limit the amount of service to be engaged in (three to fifteen hours), if the candidate desires to complete his work in one year, while but eighteen state that special consideration will be given the exceptional student if he endeavors, despite assistant's duties, to complete the work in the minimum period.

N. M. GRIER

DARTMOUTH COLLEGE

SAND FLOTATION

THE article on "Sand Flotation in Nature" given in SCIENCE for April 16, 1926, reminds me of certain observations I made on this phenomenon about twenty-five years ago. Surface tension is evidently the explanation of this flotation, but what especially interested me was the question how the sand, not necessarily in very fine grains, came to be deposited on the surface of the water so gently as to remain there. I found by observation that, in some cases at least, this occurs as follows: A gentle ripple, perhaps the last movement of a broken wave, runs up a beach, covering sand that has been dried and heated by the sun. As the water recedes, the very edge of it has a rolling motion, rolling toward the sea, and in this revolution it picks up some of the sand particles, probably by creating a partial vacuum over them for a moment, and then floats them off.

I have successfully imitated nature in this maneuver, using well-dried and perhaps slightly greasy sand in a domestic baking-pan. It is my impression that I published an account of all this in the *Youth's Companion*, probably about 1901.

EDWIN H. HALL

HARVARD UNIVERSITY

REQUEST FOR PUBLICATIONS IN THE FIELD OF ATMOSPHERIC ELECTRICITY

WE are planning to write an extensive treatise on atmospheric electricity and allied phenomena which will be published next year.

On account of the unfortunate shortage of funds of the libraries in the Austrian universities it is extremely difficult for us to obtain all journals and especially the bulletins and proceedings of the scientific institutions and societies in foreign countries.

It would be a great help to our work if the physicists and meteorologists in all English speaking countries would kindly send us reprints of their publications pertaining to atmospheric electricity including electric field of the earth and atmosphere, ionization of the atmosphere, thunderstorm electricity, electric properties of rain and snow, radioactivity of the earth and atmosphere, rays of cosmic origin, electric currents in the atmosphere, polar light, theories of the origin of the atmospheric-electric phenomena and propagation of electric waves around the earth.

All colleagues who are willing to assist us are asked to send reprints of their publications to the address given below.

H. BENNDORF

V. F. HESS

PHYSIKALISCHES INSTITUT,
UNIVERSITÄT GRAZ (AUSTRIA)

SCIENTIFIC BOOKS

Researches on Fungi. Vol. III, The Production and Liberation of Spores in Hymenomycetes and Uredineae. By A. H. REGINALD BULLER. Longmans, Green and Co., 1924. pp. 611.

THIS is the third volume of Buller's "Researches on Fungi," and at least one more is promised. It takes an ambitious, resourceful and trained scientist to turn out, as a side issue to teaching, work of the character of these books. The latest volume contains 611 pages of descriptive matter, including the table of contents and general index, and is illustrated with two hundred and twenty-seven drawings and photographs about equally numerous. The text includes not only observations made by the writer and his pupils, but also reference to work of previous investigators.

The book is divided into two parts of which Part I is by far the larger. This deals in the first eleven chapters with a technical discussion of the production and liberation of the spores in the Hymenomycetes; chapter XII treats of luminescent fungi; chapter XIII, with parasitic agarics; chapter XIV, with nocturnal spore discharge. Part II is concerned with the production and liberation of basidiospores in

the Uredineae. A summary of each chapter at the end of the book gives the hurried reader a chance to grasp the main features of the work. The book is dedicated to the long and favorably known English mycologist, William P. Grove. Space does not permit a detailed outline of the work, but some general idea of the fungi dealt with can be seen by the following short summary.

The Psathyrella sub-type of mushrooms is illustrated chiefly by *Lepiota cepaestipes* which takes twenty-two pages of descriptive matter, while *Lepiota procera* occupies six more of the first chapter, and *Psathyrella disseminata* takes up the second chapter of thirty-one pages. Chapter III deals with the Bolbitius sub-type, chiefly *B. flavidus,* and a comparison with the fruiting body of the genus Coprinus. The IV chapter treats, in more or less detail, with *Armillaria mellea, Marasmius oreades, Amanita rubescens, Amanitopsis vaginata,* Collybia sps. (chiefly *C. radicata*), *Pluteus cervinus* and *Nolanea pascua.* Chapter V is short, dealing with another sub-type illustrated by Inocybe. Chapters VI to XI, comprising two hundred and thirty-nine pages, treat of the Coprinus like fungi of which details are given of *Psathyra urticaecola, Coprinus plicatilis, C. comatus, C. sterquilinus* (treated in detail), *C. atramentarius, C. stercorarius, C. picaceus, C. lagopus* and *C. micaceus.*

The remaining chapters of this first part deal with the toadstools from a different point of view. For example, chapter XII treats of bioluminescence, giving detailed observations made on *Panus stypticus* form *luminescens,* found in North America, the European representative of this species apparently being non-luminous. A list of eighteen luminescent mushrooms is given and short notes are included on other fungi, bacteria and animals in which this phenomenon has been observed. Chapter XIII deals with fungi parasitic on other fungi, details being given of those agarics found on other agaric species. The final chapter treats of the nocturnal spore discharge of species of Pleurotus and a method of detecting it by an electric hand-lamp.

Part II of the book is comparatively short, dealing with the Uredineae in three chapters. The first of these considers the phenomena of spore discharge as illustrated by species of Puccinia, Endophyllum and Gymnosporangium. Chapter II discusses the teleutospore and the curvature of its basidium in relation to the dispersal of the basidiospores, illustrated chiefly by the germination of *Puccinia malvacearum.* Chapter III concludes the work with a discussion of spore walls and the dispersal of spores by water and wind.

While on the whole these books of Buller's are of chief value to the mycologist, there is much of interest to the general student of nature. Manitoba seems very remote even to an American, yet when an English trained botanist makes it his home and turns out such stimulating and exact work, we realize more fully than ever that the man, rather than the environment, counts most.

G. P. C.

Tales of Fishing in Virgin Seas. By ZANE GREY, author of Tales of Fishes, etc., etc. Harper & Brothers, New York.

ZANE GREY'S "Tales of Fishing in Virgin Seas" is an angler's book de luxe. It is elegantly printed on fine paper in large clear type, with a hundred illustrations, handsome and instructive. It describes in detail a three months' cruise of a three-masted schooner from Nova Scotia, answering to the name of *Fisherman* (née Marshal Foch). The angling described was all for giant fish of the open sea, especially sword-fish, sail-fish, marlins, tunnies and albacores. Incidentally also were taken groupers (garrupa), barracudas, onos (Acanthocybium) papagallos (Nematistius) Cavalla (Caranx), and others of less note and size.

To the ichthyologist the book is welcome as it gives records of these giants in waters which had never been fished before. Of a new species of sail-fish or volador, described by the writer in a paper now in press, a hundred or more were caught by Mr. Grey and his associates, and several excellent photographs are presented. Useful accounts are given of the ways of several of the marlins ("Marlin spike-fish") and of the yellow finned tunnies. A black marlin similar to others of Hawaii and Japan (Makaira mazara) was obtained off Guerrero in Mexico, and a good photograph given. Some other species may be new to science, but without good photographs one can not be sure. It is from photographs only that we can define most of these species, as mounted examples and casts must remain rare, and a black marlin of half a ton or more, or even a sword-fish of half that size, does not rest comfortably in a bottle.

DAVID STARR JORDAN

SCIENTIFIC APPARATUS AND LABORATORY METHODS

OIL-WATER MODELS ILLUSTRATING SURFACE FORCES AND FILMS IN BIOLOGICAL PHENOMENA

THE following models have been found useful as demonstration experiments in connection with the courses in pharmacology in this laboratory. They simulate the phenomena of Brownian motion, ameboid motion, pseudopod formation, contractility, cytolysis, chromatolysis, phagocytosis, anesthesia and selective swelling. The phenomena of adsorption, diffusion,

lipoid solubility, competition of solvents, permeability, etc., which are responsible for the kinetic phenomena, are simultaneously illustrated. It is believed the experiments help to visualize cell surface phenomena and illustrate their physical-chemical basis.

The experiments are conveniently demonstrated to groups of students, or the results may be projected on a screen before the entire class. As the experiments can be quickly repeated without trouble, either method is convenient. Students may practice the experiments themselves, but we have found it more satisfactory to demonstrate them. The brief explanations and suggestions accompanying the following directions make no pretense at completion and are included with the hope of stimulating the student's imagination in the application of physical-chemical principles in the fundamental aspects of pharmacological phenomena.

SURFACE FORCES AND FILMS AND ANTAGONISM OF CALCIUM IN CONTRACTILITY

The castor oil used in all the experiments is colored red with 0.5 per cent. of scarlet red.

Three drops of castor oil are placed on distilled water in 4 evaporating dishes and on tap water in one dish; immediate spreading of the castor oil. Then add the following reagents, one to each dish:

(1) *Soap Granule*: Immediate constriction of castor oil drops.[1]

(2) *Turpentine*: Gradual constriction of castor oil drops, which return to previous size as the turpentine film constricts. The tendency to spread in distilled water is less than in tap water or distilled water containing salt. Addition of enough turpentine to make a film over all the water causes permanent constriction of the castor oil.

(3) *Kerosene*: Castor oil drops remain unchanged and kerosene film shows no marked tendency to spread, but when the water phase is stirred the castor oil drops constrict.

(4) *Caprylic Alcohol*: Immediate constriction of castor oil. The caprylic alcohol breaks up explosively, shooting small droplets from its periphery, which spread out, producing streams with definite direction. When the activity is over, the castor oil drops increase to a greater extent than before and show sluggish movements.

(5) *Antagonism of Calcium*: Add a granule or touch a bar of soap to tap water or distilled water containing a little calcium chloride (about 0.0025 per cent.), on which have been spread three drops of castor oil; immediate constriction of oil drops which return to previous size on withdrawal of the soap, simulating recovery from, or relaxation after, contraction. The contraction-relaxation, simulating pulsation, may be repeated several times. High concentrations of soap or calcium tend to obscure the phenomena. Sodium chloride is ineffective. The addition of calcium to the soap-oil experiment in distilled water is ineffective, perhaps owing to unreactivity (insolubility) of calcium in the lipoid soap interface.

At least two explanations of the changes in the castor oil suggest themselves. A drop of oil on water assumes a shape conditioned by at least three factors: (a) Its own cohesive forces, leading to surface tension, which tends to cause it to assume a spherical shape with minimum diameter; (b) gravitation, which tends to flatten out the drop, increasing its horizontal diameter; (c) the cohesive force of the molecules of water, *i.e.*, the surface tension of the water, resisting the deformation of the water surface by the oil drop. The greater this force the less can the drop assume a spherical shape, and the drop must thus acquire a greater horizontal diameter. Accordingly, anything increasing the surface tension of the oil will lead to a decrease in the horizontal diameter, *i.e.*, a constriction, and conversely, anything increasing the surface tension of water will cause a spreading of the oil drop. Thus, the constriction from soap, caprylic alcohol, kerosene and turpentine may be explained as due to their lowering surface tension of water. All the agents used lower surface tension of water, but they do not constrict the oil drops to an equal degree. Therefore, another possibility is suggested, namely, the formation of a film of the added substance upon the surface of the water, so that a lateral circumferential pressure is exerted on the drop. This force is quite conceivable apart from surface tension changes. In fact, the films of soap and kerosene are recognizable with the naked eye.

The changes resulting from withdrawal of the soap in tap water, or distilled water containing calcium, are due to the influence of this bivalent ion, rupturing the film of soap by precipitation, thus liberating the castor oil which spreads. The fact that an excess of soap in tap water, or of calcium in distilled water, may obscure or prevent the spreading phenomenon suggests the importance of an accurate ionic balance and concentration such as exist in finely adjusted and sensitive biological systems. The influence of low concentrations of calcium on the oil drop phenomena suggests further something of the ease with which disturbances in function may be produced by this ion in virtue of surface effects.

[1] The castor oil-soap experiment was suggested to us by Professor Torald Sollmann.

BROWNIAN MOTION, CYTOLYSIS AND ANTAGONISM OF SOAP

(1) *Brownian Motion:* Place a drop of caprylic alcohol colored with scarlet red on water in an evaporating dish; immediate breaking up, shimmering and scattering from the periphery of each droplet in all directions. The constant instability reminds one of Brownian motion. The tendency of caprylic alcohol to break up and shimmer on water suggests lowering of surface tension of the water.

(2) *Cytolysis:* Same arrangement as above. Add a drop of caprylic alcohol to a drop of castor oil on a water surface; immediate breaking up of the oil drop from the bombardment by caprylic alcohol particles and simulating cytolysis.

(3) *Antagonism of Soap:* The addition of caprylic alcohol to castor oil on a water surface containing soap prevents dispersion of the oil, and the caprylic alcohol spreads over the castor oil drops and encloses them like a cytoplasmic covering. Apparently the soap film protects the oil and antagonizes the action of caprylic alcohol, though both soap and caprylic alcohol lower the surface tension of water.

ANESTHESIA AND DIFFERENCE BETWEEN LIQUID PETROLATUM (HYDROCARBON) AND CASTOR OIL (TRUE FAT)

(1) Place a castor oil drop on a water surface and expose to ether vapor by holding the tip of a pipette containing a small drop of ether in close proximity to the castor oil; expansion of the oil drop, simulating relaxation as in anesthesia. When the ether is withdrawn, the drop contracts to its previous size, simulating recovery from the anesthetic. Lipoid solubility with increase in volume of the drop and accumulation of ether at the surface resulting in lowering of surface tension are suggested as the explanation of this phenomenon. This action is counteracted if a granule of soap is previously placed in the water phase. Apparently a soap film is more powerful than the expanding effect of ether, the expenditure of energy in the system being rather marked.

(2) Place a drop of liquid petrolatum on a water surface and expose to ether vapor as above; no alteration in size of the liquid petrolatum, despite the good lipoid solubility of ether in this oil. It may be assumed that a different structure at the liquid-liquid interface has modified the response of liquid petrolatum to ether. Liquid petrolatum being without active polar groups does not combine with the water and adsorb the ether at the interface, while castor oil has active polar groups which combine with the water and with the ether. Apparently not all agents, or contractile tissues, behave alike toward anesthetics.

PHAGOCYTOSIS; AMOEBOID MOTION AND PSEUDOPOD FORMATION

(1) Place a drop of nitrobenzol alongside a drop of colored castor oil spread on a water surface; ingestion of nitrobenzol, suggesting phagocytosis in virtue of lipoid solubility. Then a gradual abstraction of the dye from the castor oil by the nitrobenzol supervenes due to competition of solvent for the dye and simulating exchange of metabolite.

(2) Same arrangement as in (1) above, but with a granule of soap in the water phase. The same phenomenon occurs, but much more slowly. There is an increase in size of the oil drop, suggesting swelling, and alteration in its contour and shape, suggesting pseudopod formation. Here again the opposition of a soap film is demonstrated, this time against the lipoid solubility of nitrobenzol, and swelling.

MEMBRANE FORMATION AND ACTIVITY

(1) Place a drop of nitrobenzol upon a drop of colored castor oil on a water surface. A double ring forms within the castor oil consisting of a pale red outside ring and a deep red inside ring, the latter suggesting membrane formation from concentration of solute. The scarlet red passes into the space surrounded by the deep red ring (competition of solvent), which increases in size until it occupies the whole drop suggesting an active rôle of the membrane which allows a solute to pass through into the cell, and in consequence swelling of and increased pressure within the cell.

(2) Nitrobenzol dropped upon a diffuse drop of castor oil on water concentrates and ingests the oil drop as shown by swelling of the nitrobenzol drop and accumulation of dye within it due to competition of solvents for dye, and lipoid solubility, the oil being dissolved in nitrobenzol and illustrating a type of selective swelling.

NUCLEAR ACTIVITY, CHROMATOLYSIS, VACUOLE FORMATION, AND INTERCHANGE OF PRODUCTS BETWEEN CYTOPLASM AND NUCLEUS (RESPIRATORY ACTIVITY)

Place a drop of colored castor oil on a water surface containing soap. Cover the castor oil drop with caprylic alcohol colored with a little crystal violet. This gives a bluish cytoplasm-like envelope around the drop of red castor oil which acts as a nucleus. Then place a small piece (about ½ mm long) of soap within the caprylic envelope; the soap moves about energetically and vacuole formation and rupture of the nucleus (chromatolysis) are induced. Gradually, the color of the caprylic envelope changes from bluish to reddish blue, the dye passing into the caprylic alcohol in virtue of lipoid solubility and competition of solvent, the whole simulating inter-

change of products between cytoplasm and nucleus, or respiratory activity.

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A NEW TYPE OF ELECTRON SPECTROGRAPH

THE slit system of the instrument is essentially a Hull magnetron with a very narrow slit in the anode. This slit is parallel to the oxide coated filament which is mounted on the axis of the cylindrical anode and the whole is placed in a uniform magnetic field parallel to the filament. Before the electrons reach the anode they are acted on by both the radial electric field and the magnetic field as in the magnetron, but those which pass through the slit travel in circular paths under the action of the magnetic field alone. The condition for the focussing of the electrons is that they shall traverse a semi-circumference after passing the narrowest aperture in their path, and an analytical consideration of the angles of emergence from the slit shows that in a plane perpendicular to the filament, this condition is satisfied on the line through the filament perpendicular to that joining it and the slit. This focussing is very sharp, even for electrons accelerated by less than 30 volts if small electron currents are used, and it has been suggested that this may furnish an extremely accurate direct method of determining e/m.

With this apparatus, preliminary unpublished work, indicating that commercial photographic emulsions are very insensitive to electrons accelerated by about 30 volts or less, has been confirmed. It has been found, however, that when the emulsion is covered with a very thin film of fluorescent lubricating oil, it is sensitive to electrons of much lower velocities and its sensitivity to those of higher velocities is increased by 40 or 50 times.

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SPECIAL ARTICLES

ILLINIUM

AN important result of the development of Moseley's atomic number rule has been the impetus it gave to the search for missing elements. It is true that later arrangements of the Periodic Table indicated that eka-caesium, eka- and dwi-manganese, and eka-iodine were missing, but there were no theoretical grounds for supposing that eka-neodymium might exist, until Moseley's rule showed that element number 61 was still to be identified. Moseley's work was of inestimable value to one engaged in completing the list of chemical elements for several reasons: first, it gave definite information as to the existence and location of gaps in the Periodic Table; second, it gave a basis for the calculation, prior to its discovery, of the X-ray spectrum of an element and indicated a technique by which lines in that spectrum might be identified; and finally, it gave origin to a method of examination so searching that a mixture of two elements, so closely similar in chemical properties as to be almost inseparable, could be definitely analyzed. Were it not for the work of Coster and Hevesy on the X-ray examination of zirconiferous minerals, the presence in them of element number 72 would probably be still unsuspected and hafnium, or celtium, would still be listed among the rare earths. Chemical tests made on zirconium ores had frequently indicated the non-homogeneity of zirconium, but they could not give the definite proof afforded by an X-ray analysis.

The proof that a rare earth element was missing, whose atomic number would place it between neodymium and samarium, explained the sharp break in the sequence of properties that comes in the rare earth group between those two elements. The differences in solubilities of the double salts formed by rare earth nitrates with magnesium nitrate, appear to be quite uniform, excepting in the case of neodymium and samarium, since fractional recrystallization of that double salt will accomplish a strikingly sharp separation of those two elements. There is the same break in the sequence of solubilities of other salts, in basicity, as indicated by the rate of hydrolysis, etc. It also appears that the absorption spectra show the same general variation, and, as will be shown later, the absorption bands of number 61 seem to fit into the regular sequence.

Because element number 61 might be expected to share the striking similarity in properties and the common occurrence in minerals of the other members in the rare earth group, it seemed logical to institute a search for it in monazite sands, a mineral in which the first members of that family, the so-called cerium earths, predominate. Since that mineral is rich in neodymium, 60, and in samarium, 62, it would be surprising to learn of the absence of 61 there and its presence in a mineral containing little or none of 60 and 62.

The original material used in the investigation was the rare earth residue remaining from monazite sands after the extraction of thorium and part of the cerium for use in the manufacture of Welsbach mantles. It was donated to the laboratory by the Lindsay Light Company, of Chicago. After the remaining cerium was removed by the usual methods, the other rare earths were fractionally recrystal-

lized as double magnesium nitrates. Very pure neodymium and samarium, the latter subjected to further purification by other methods, were sent to the Bureau of Standards at Washington for use in an extensive investigation being pursued on the infra-red arc spectra of the rare earths. It was found that a number of identical new lines were present in both samples and the suggestion was made that they might be due to the presence of a small amount of a new element. Eder had noted the same phenomenon. Later, when the ultra-violet arc spectra of neodymium, samarium, and of intermediate fractions containing both, were examined, lines common to all three were found. However, X-ray analysis of those same samples showed no indication of the presence of an element with atomic number 61. Prandtl and Grimm had subjected rare earth material to separation by the same method and then to a fractional precipitation with ammonia, and could find no evidence of the missing element by X-ray analysis.

It seemed that the solubility of the double magnesium salt of 61 is very similar to that of neodymium and its separation by recrystallization of that salt offered little hope of success. The order of solubility of the bromates of the cerium group earths is the reverse of the order obtaining with the double magnesium nitrates and that suggested a means of separating neodymium and thus concentrating 61. It is easier to separate a small amount of one element from a larger amount of a second, if the former is in the less soluble end of the series of recrystallizations. Accordingly the neodymium rich material thought to contain 61 was converted to bromate and again recrystallized.

A marked change in the absorption spectra of the solutions that began to appear after repeated recrystallization indicated the probable concentration of the missing element. Two bands, one at 5816A° and one at 5123A°, that had shown very faintly in supposedly pure neodymium, became stronger in some fractions as the other neodymium bands disappeared. Because these two bands, if assigned to number 61, find their places in a more or less regular sequence shown by bands of neighboring elements it was thought they might belong to that element.

X-ray analysis confirmed the theory and showed the presence of number 61 in those fractions. A mean value of five determinations of 2.2781A° was found for the $L\alpha_1$ line and one determination of 2.0770A° for the $L\beta_1$ line. A faint indication of the $L\beta_3$ line was also noted. It is assumed that these results prove the presence of element number 61.

The name assigned to the element is Illinium (Il).

There are several reasons that may be advanced to explain why the element escaped detection by means other than X-ray analysis. It must be extremely rare. Its solubility in a series of fractional recrystallization is next to that of the very abundant neodymium, which tends to spread into the illinium-rich members of a series. The large number of absorption bands exhibited by both neodymium and samarium would tend to mask its absorption spectrum. Finally the solubility of its double magnesium nitrate, which salt is commonly used for the separation of closely related elements, is close to that of neodymium. Evidence supporting this latter is found in the fact that the absorption bands at 5816A° and 5123A° found in supposedly pure neodymium purified by that method, are shown to belong to illinium.

The identification of illinium as the missing rare earth completes the list of rare earth elements. Work has been instituted involving the extraction of several hundred pounds of the crude material with the purpose in view of obtaining enough of the element in pure enough state to study its properties, its relationship to other members of the group and its atomic weight.

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THE EFFECT OF AN ELECTRIC FIELD APPLIED TO A PHOTOGRAPHIC PLATE DURING EXPOSURE[1]

BEFORE the development of the modern silver bromide plate there were many attempts to increase the sensitivity of photographic processes by the application of an electric field or an electric current to the sensitive material during exposure.[2] In some of these attempts slight changes of sensitivity were detected, and in others no effect was observed. Because of astronomical and spectroscopic applications, it is important to know whether a really significant change of sensitivity can be obtained.

We have performed some experiments on the effect of an electric field applied perpendicular to the surface of the plate under conditions which, so far as we can learn, have not been utilized in previous investigations.

There are at least two ways in which we may hope to produce such a change in plate sensitivity. The first is based upon the fact that when light of sufficiently great frequency falls on silver halide crystals it increases their conductivity,[3] and on the fact that

[1] Published by permission of the director of the Bureau of Standards.

[2] Eder, Handbuch der Photographie, Vol. 1, Part 2, p. 421, (3rd edition), gives references to all the earlier work.

[3] Arrhenius, Sitz. Ber. d. Wiener Akad., II Abteilung, 96, p. 831, 1887. Eder's Jahrb. 9, p. 201, 1895.

they exhibit the photoelectric effect.[4] It is probable also that charges may be liberated inside the gelatine by the action of light. If a potential gradient can be applied to the emulsion, a current will flow and may affect the formation of the latent image in a variety of ways. To realize these conditions, we placed a plate between a sheet of aluminum foil and a sheet of fine meshed nickel gauze, and applied potentials of the order of 1,200 volts to these electrodes, while the plate was exposed to a quartz mercury arc (Labarc). After a few trials we decided to use gold foil for the front electrode, since we found that it transmits down to at least 2,200 A. U. In this way the field could be applied to the emulsion more uniformly, though variations in the thickness of the foil gave a mottled appearance to the exposed portions of the plate. This was of no consequence in judging the relative density of exposures obtained with and without the field, for we are interested only in large changes of sensitivity. The possibility of error due to irregularity of the foil was eliminated by the simple expedient of taking a large number of plates, each with a different piece of foil.

With this arrangement of apparatus, the emulsion was in contact with only one electrode, so we could not expect any effect from the use of a potential applied always in one direction. This would simply result in the charging up of the emulsion. However, for the sake of completeness, both direct current and 60 cycle alternating current were tried.

A second way in which we may hope to increase the sensitivity of a plate is this: Mount a rectangular frame carrying a sheet of gold foil a short distance in front of the emulsion (1 to 2 mm). The other electrode may be in contact with the emulsion or may be applied to the glass side of the plate. If the gold foil is charged to a high negative potential (say 1,200 volts) with respect to the emulsion, photoelectrons liberated from the foil will strike the plate with velocities sufficient to affect it. If the positive electrode is in contact with the emulsion, this effect alone is operative, while if it is applied to the back of the plate we can utilize both the electronic bombardment and the effects due to charges liberated inside the emulsion.

Unfortunately, the efficiency of photo-ionization from solids is extremely low,[5] so that the number of photo-electrons passing from foil to plate may be very small compared with the number of light-quanta transmitted. However, it is known that several hundred quanta are required to render a silver bromide grain developable, while Kinoshita[6] and Svedberg[7] state that only a single alpha particle is needed for each developable grain. We have no data on the photographic efficiency of 1,200-volt electrons, but in view of the energy they possess it seems reasonable to assume that only a few may be required for each developable grain. In the entire absence of quantitative data applicable to the case under consideration, we tried the experiment. Since the gold foil used transmitted only a small percentage of the light incident upon it, conditions favored the detection of effects due to the photoelectrons liberated.

Now that the principles involved are clear, we shall describe the details of the work. A complete series of tests was made with each of the three electrode arrangements described above. With each arrangement we tried both direct and 60 cycle alternating current. The direct current was applied in both directions, and the results were compared, but no difference in the density could be observed. Ordinarily, when we were interested only in comparing the densities obtained with and without the applied potential for a given arrangement of polarities and of apparatus, four rectangular areas were exposed on each plate. The first was exposed without field, the second and third with field, and the fourth without field, to check up on the constancy of the light source.

Separate series of exposures were made to test the effect of applying a field and then exposing to light, or that of exposure followed by the application of a field.

It is obvious that when experiments of this kind are performed in air, photoelectrons from the foil will not reach the plate with velocities corresponding to the full impressed potential; further, the potential which can be applied is limited by the formation of brush discharges through the air. For these reasons all the experiments described above were repeated in vacuo, using a Pyrex tube having a large ground glass joint which carried a fused quartz window. The tube was kept on a mercury diffusion pump while exposures were being obtained. The gas pressure was below that which could be read on a Macleod gauge easily capable of detecting 10^{-4} mm. With this apparatus, direct current potentials of 1,500 volts could be utilized; but, with alternating current, capacity discharges took place at 1,200 volts because of the presence of the vapors of stop cock grease from the ground joint. In view of the absence of any positive results, it was not thought worth while to build an apparatus which would permit the attainment of really good vacuum conditions.

[4] Schmidt, *Annalen der Physik*, 64, p. 718, 1898.

[5] Data of Elster and Geitel (*Phys. Zeit.*, 13, p. 468, 1912), quoted on p. 59 of Hughes's "Photoelectricity," show that electrons liberated from a potassium hydride surface carry only about 1/2300 of the energy of the incident light.

[6] Proc. Roy. Soc. A, 83, p. 432, 1910.

[7] *Photographic Journal*, 61, p. 325, 1921.